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Marine Mammal Bycatch in U.S. West Coast Groundfish Fisheries, 2002–19

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NOAA FISHERIES

Marine Mammal Bycatch in U.S. West Coast Groundfish Fisheries, 2002–19

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U.S. DEPARTMENT OF COMMERCE

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Contents

Figures

Tables

Plain Language Summary

Background

Marine mammals are a diverse group of creatures that spend some or all of their time in the ocean. This group includes whales, dolphins, seals, sea lions, sea otters, and polar bears. Over 30 species of marine mammals live near or visit the U.S. West Coast, where they unfortunately can fall victim to human activities. Some of these impacts include noise from ships interfering with whale sonar, whales and dolphins being struck by ships, toxic chemicals in the water, and getting tangled in active or derelict fishing gear.

NOAA Fisheries has a duty to protect and preserve these vulnerable animals. The U.S. Marine Mammal Protection Act protects them by imposing limits on the numbers that can be targeted or caught accidentally in U.S. fisheries. In addition, the Endangered Species Act protects any marine mammals that are listed as threatened or endangered. On the U.S. West Coast, this includes humpback whales, the iconic Southern Resident killer whales, and Guadalupe fur seals.

At the Northwest Fishery Science Center's observer program, we track how many marine mammals are caught and/or killed each year by commercial fisheries. Incidentally caught marine mammals, or "bycatch," are easily spotted by onboard observers, as they are usually much larger than the fish being targeted by the vessel.

We collect data by direct observation, electronic monitoring, and from fish sales information. Fishing vessel crew are required to report all marine mammal bycatch to observers or NOAA Fisheries. This report summarizes marine mammal bycatch in commercial fisheries and is shared with the Pacific Fishery Management Council to help them make management decisions.

The observer program monitors marine mammal bycatch in the following fisheries:

- Limited entry bottom trawl.
- Individual fishing quota bottom trawl, hook-and-line, pot, midwater rockfish, and midwater Pacific hake.
- Limited entry sablefish (endorsed and nonendorsed).
- Open access and nearshore fixed gear (hook-and-line and pot).
- The pink shrimp, California halibut, ridgeback prawn, sea cucumber, directed Pacific halibut, and at-sea Pacific hake fisheries.

Definitions of and details on these fisheries can be found throughout this report.

This technical memorandum provides marine mammal bycatch estimates for the years 2002 through 2019. Estimates are in metric tons (mt), and are broken out by fishery sector.

Key Takeaways

We present data by fishery sector, as well as by species. We also provide data on nonlethal interactions and sightings of marine mammals.

- California and Steller sea lions are the most commonly killed marine mammals in the U.S. West Coast groundfish fisheries.
- Harbor seals and northern elephant seals are common bycatch in these fisheries as well.
- No sea otters or Guadalupe fur seals have been observed taken or killed in any of these fisheries throughout the time series.
- Common bottlenose and Pacific white-sided dolphins have been taken in these fisheries.
- Humpback whales have been killed in both the limited entry sablefish and open access pot fisheries.
- In 2016, a single northern right whale dolphin was taken by a Pacific hake catcher vessel.
- In general, most of our charts show the numbers of marine mammal bycatch dropping over time.

Links used in this section:

- Marine mammals: https://www.fisheries.noaa.gov/resource/educational-materials/marine-mammals-us-north-pacific-arctic
- Toxic chemicals in the water: https://repository.library.noaa.gov/view/noaa/12818
- Marine Mammal Protection Act: https://www.fisheries.noaa.gov/topic/laws-policies#marine-mammal-protection-act
- Endangered Species Act: https://www.fisheries.noaa.gov/topic/laws-policies#endangered-species-act
- Humpback whales: https://www.fisheries.noaa.gov/species/humpback-whale
- Southern Resident killer whales: https://www.fisheries.noaa.gov/species/killer-whale
- Guadalupe fur seals: https://www.fisheries.noaa.gov/species/guadalupe-fur-seal
- Observer program: https://www.fisheries.noaa.gov/west-coast/science-data/fisheries-observation-science-west-coast
- Direct observation: https://www.fisheries.noaa.gov/topic/fishery-observers
- Electronic monitoring: https://www.fisheries.noaa.gov/west-coast/resources-fishing/electronic-monitoring-west-coast
- Pacific Fishery Management Council: https://www.pcouncil.org/

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Executive Summary

The California Current marine ecosystem on the U.S. West Coast (Washington, Oregon, and California) supports a diversity of marine organisms, including marine mammals. Managing and conserving marine biodiversity requires accounting for human-induced mortality to marine mammals. The distributions of marine mammals overlap with commercial fisheries operating within the U.S. Exclusive Economic Zone (EEZ), and can cause incidental fishing mortality of these species (a.k.a. "bycatch"). This report summarizes interactions between the U.S. West Coast groundfish fishery and marine mammals, and presents estimates of fleetwide bycatch for these species based on landings data from these fisheries, as well as electronic monitoring (EM) and federal observer programs during 2002–19.

We used Bayesian time-series models to estimate marine mammal bycatch in fisheries with less than 100% monitoring (Jannot et al. 2021). The majority of marine mammals killed by U.S. West Coast groundfish fisheries are pinnipeds, primarily California sea lions followed by Steller sea lions, both of which are most often captured in trawl gear. Northern elephant and harbor seals are the most frequently caught seals (Phocidae), with roughly similar numbers being caught in both trawl and hook-and-line fisheries. In 2019, a northern elephant seal was recorded as a take for the first time in a pot fishery. Between two and four unidentified pinnipeds are also killed each year in these fisheries. Guadalupe fur seals and sea otters have not been observed taken or killed by these fisheries.

The majority of small cetaceans taken in the U.S. West Coast groundfish fisheries are common bottlenose dolphins, followed by Pacific white-sided dolphins. The first observation of a northern right whale dolphin take was recorded in 2016 in the Pacific hake catcher vessels that deliver to motherships at-sea sector. A number of small cetacean species that were killed by trawl fisheries prior to the implementation of the catch share program (2011) have not been observed as bycatch in these fisheries since 2011. Humpback whales have been taken in both the limited entry sablefish and the open access fixed gear pot fisheries, and represent the only species listed under the Endangered Species Act taken by these fisheries, as well as the only large cetacean taken by any U.S. West Coast groundfish fishery. Table 1 summarizes the estimated pinniped and cetacean mortality by gear in U.S. West Coast groundfish fisheries.

Table 1. Estimated mean (95% credible interval) number and percent of cetacean and pinniped mortality for each gear type for the most recent three years of data.

Group	Gear	Mean (CI), 2017	%, 2017	Mean (CI), 2018	%, 2018	Mean (CI), 2019	%, 2019
Cetaceans	Trawl	2.00 (0–5)	48	0.00 (0–0)	0	0.00 (0–0)	0
Cetaceans	Pot	1.47 (0–4)	35	1.19 (0–4)	62	1.16 (0–4)	58
Cetaceans	H&L	0.73 (0–3)	17	0.72 (0–3)	38	0.86 (0–3)	42
Pinnipeds	Trawl	125.23 (104–148)	88	73.35 (57–91)	84	70.83 (55–88)	85
Pinnipeds	H&L	16.96 (9–25)	12	14.46 (8–22)	16	11.49 (5–19)	14
Pinnipeds	Pot	0.00 (0–0)	0	0.00 (0–0)	0	1.00 (0–3)	1

1 Introduction

The California Current marine ecosystem on the U.S. West Coast (Washington, Oregon, and California) supports a diversity of marine organisms, including marine mammals. Managing and conserving marine biodiversity requires accounting for human-induced mortality to marine mammals. The distributions of marine mammals overlap with commercial fisheries operating within the U.S. Exclusive Economic Zone (EEZ), and can cause incidental human-induced mortality of these species (a.k.a. "bycatch"). This report summarizes interactions between the U.S. West Coast fisheries that incidentally catch marine mammals during fishing operations, and presents estimates of fleetwide bycatch for marine mammals using data from fishery landings (PacFIN), federal observer programs during 2002–19, and electronic monitoring (EM) programs.

The large ranges and global distribution of marine mammals make them susceptible to mortality from numerous human activities, including hunting, transportation, oil and gas extraction, and commercial fisheries (IWC 1994, Whitehead et al. 2000, Gales et al. 2003, Reeves and Stewart 2003, Helm et al. 2015, Avila et al. 2018). Fisheries bycatch has been identified as one of the most serious threats to marine mammals (Reeves et al. 2013, Avila et al. 2018), with estimates of marine mammal bycatch at least 650,000 individuals globally each year (Read et al. 2006) This number is probably an underestimate because of large data gaps (Gray and Kennelly 2018). In the United States, total estimated marine mammal bycatch declined from a high of more than 8,000 animals in 1992 to about 4,000 in 1999 (Read et al. 2006). The decline is thought to be due to the introduction of the U.S. Marine Mammal Protection Act (Read et al. 2006).

Species-specific characteristics such as migration routes, feeding locations and times, diet preferences, body sizes, and individual physical conditions play a role in susceptibility of marine mammals to fishing mortality. The general life-history strategy of marine mammals—delayed maturity, low reproductive output, large body size, long life span—makes their populations vulnerable to decline. Historically, these species had high rates of subadult and adult survival, which allowed individuals to offset low reproductive output with high investment in offspring survival to maturity (Stearns 1992, Lewison et al. 2004), so even small amounts of mortality can have large population-level impacts.

1.1 U.S. Marine Mammal Management

Currently, there are two key federal environmental laws in the United States that regulate actions concerning marine mammals: the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA). The MMPA explicitly protects marine mammals, whereas the ESA is relevant to species identified as threatened or endangered and offers additional measures for protection of ESA-listed marine mammals beyond the MMPA. Further details of these federal acts are described below. In addition, the Magnuson–Stevens Fishery Conservation and Management Act directs the United States to report on and minimize fishery bycatch, including marine mammal bycatch (MSA 2006).

1.1.1 Marine Mammal Protection Act

The MMPA was passed in 1972, reauthorized in 2006, and most recently amended in 2018 (MMPA 2018). The Act states that marine mammal species and population stocks should not be permitted to diminish below their optimum sustainable population (OSP) level and that measures must be taken to replenish depleted species or populations. Measures include reducing the take of marine mammals in U.S. waters and by U.S. citizens on the high seas and the importation of marine mammals and marine mammal products into the United States. The MMPA contains specific provisions for reducing marine mammal bycatch in U.S. commercial fisheries (MMPA 2018).

All marine mammals are protected under the MMPA. The MMPA directs agencies to identify marine mammal stocks that are depleted and/or strategic. The MMPA defines a depleted stock as any marine mammal stock that is below its OSP or is listed as an endangered species or a threatened species under the ESA.

The MMPA defines a strategic stock as any marine mammal stock for which:

- The level of direct human-caused mortality exceeds the potential biological removal.
- The best available data indicate the population is declining and is likely to be listed as a threatened species under the ESA within the foreseeable future.
- The status is threatened or endangered under the ESA, or depleted under the MMPA.

The MMPA statuses of stocks listed in Tables 2 and 3 were obtained from the most recent marine mammal stock assessments (Carretta et al. 2020b, Muto et al. 2020).

Effects of U.S. commercial fisheries on marine mammal populations are determined annually and reported in the List of Fisheries (LOF), which is published by the National Marine Fisheries Service (NMFS; USOFR 2021) as required by Section 118 of the MMPA (2018). Each fishery is placed into one of three categories based on the level of marine mammal serious injury and mortality in the fishery: Category I has the highest injury/mortality level and Category III has the lowest injury/mortality level. The categorization process often relies on marine mammal stock assessment reports (SARs) to provide the potential biological removal (PBR) level of the stock that ensures a sustainable population is maintained. The categorization level of a fishery determines if compliance is required with particular provisions of the MMPA, including registration, observer coverage, and take reduction plans. Category I and II commercial fisheries are required to comply with these MMPA Section 118 provisions, while Category III commercial fisheries are not. However, all vessel owners/operators must report incidental deaths or injuries of marine mammals that occur as a result of commercial fishing operations, regardless of their fishery's category.

The U.S. West Coast groundfish fisheries included in this report are all classified as Category III commercial fisheries in the context of the MMPA, with the exception of the WA/OR/CA sablefish pot sector, which is designated as Category II (see Table 1 in USOFR 2021). For the purposes of this report, when we refer to the U.S. West Coast groundfish fisheries it encompasses both the federal fisheries that target groundfish as well as federal and state (WA, OR, and CA) fisheries that incidentally catch groundfish and carry federal groundfish observers or participate in federal electronic monitoring programs.

Table 2. Status under the MMPA, ESA, and International Union for Conservation of Nature (IUCN) Red List, and numbers of cetacean observed mortalities, nonlethal interactions, and sightings recorded by observers on U.S. West Coast fishing vessels observed by the NWFSC Fisheries Observation Science Program, 2002–19. MMPA and ESA status relates only to those populations in waters off the coasts of WA, OR, and CA. Numbers are numbers of individuals. *M/SI* = mortality/serious injury.

		Conservation status			Observed		
Common name	**Scientific name**	**MMPA**	**ESA**	**IUCN**	**M/SI**	**Interactions**	**Sightings**
Baird's beaked whale	*Berardius bairdii*	Protected	Not Listed	Least Concern	0	0	17
Blaineville's beaked whale	*Mesoplodon densirostris*	Protected	Not Listed	Least Concern	0	0	0
Blue whale	*Balaenoptera musculus*	Depleted, Strategic	Endangered	Endangered	0	0	56
Bryde's whale	*Balaenoptera edeni*	Protected	Endangered	Least Concern	0	0	1
Cuvier's beaked whale	*Ziphius cavirostris*	Protected	Not Listed	Least Concern	0	0	0
Dwarf sperm whale	*Kogia sima*	Protected	Not Listed	Least Concern	0	0	0
False killer whale	*Pseudorca crassidens*	Protected	Endangered	Near Threatened	0	0	0
Fin whale	*Balaenoptera physalus*	Depleted, Strategic	Endangered	Vulernable	0	0	47
Gingko-toothed beaked whale	*Mesoplodon ginkgodens*	Protected	Not Listed	Data Deficient	0	0	0
Gray whale	*Eschrichtius robustus*	Protected	Endangered	Least Concern	0	0	276
Hector's beaked whale	*Mesoplodon hectori*	Protected	Not Listed	Data Deficient	0	0	0
Hubbs' beaked whale	*Mesoplodon carlhubbsi*	Protected	Not Listed	Data Deficient	0	0	0
Humpback whale	*Megaptera novaeangliae*	Depleted, Strategic	Endangered	Least Concern	2	9	1,179
Killer whale	*Orcinus orca*	Protected	Endangered*	Data Deficient	0	71	588
Minke whale	*Balaenoptera acutorostrata*	Protected	Not Listed	Least Concern	0	0	31
Northern Pacific right whale	*Eubalaena glacialis*	Depleted, Strategic	Endangered	Endangered	0	0	0
Pygmy sperm whale	*Kogia breviceps*	Protected	Not Listed	Least Concern	0	0	0
Sei whale	*Balaenoptera borealis*	Depleted, Strategic	Endangered	Endangered	0	0	13
Short-finned pilot whale	*Globicephala macrorhynchus*	Protected	Not Listed	Least Concern	0	0	0
Sperm whale	*Physeter macrocephalus*	Depleted, Strategic	Endangered	Vulernable	1	41	144
Stejneger's beaked whale	*Mesoplodon stejnegeri*	Protected	Not Listed	Near Threatened	0	0	0
Common bottlenose dolphin	*Tursiops truncatus*	Protected	Not Listed	Least Concern	1	0	76
Dall's porpoise	*Phocoenoides dalli*	Depleted, Strategic	Not Listed	Least Concern	1	7	967
Harbor porpoise	*Phocoena phocoena*	Protected	Not Listed	Least Concern	1	2	206
Long-beaked common dolphin	*Delphinus capensis*	Protected	Not Listed	Data Deficient	0	0	30
Northern right whale dolphin	*Lissodelphis borealis*	Protected	Not Listed	Least Concern	1	0	4,382
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*	Protected	Not Listed	Least Concern	7	170	16,065
Risso's dolphin	*Grampus griseus*	Protected	Not Listed	Least Concern	3	0	752
Short-beaked common dolphin	*Delphinus delphis*	Protected	Not Listed	Least Concern	0	1	289
Striped dolphin	*Stenella coeruleoalba*	Protected	Not Listed	Least Concern	0	0	4

*Southern Resident population only.

Table 3. Status under the MMPA, ESA, and International Union for Conservation of Nature (IUCN) Red List, and numbers of pinniped and sea otter observed mortalities, nonlethal interactions, and sightings recorded by observers on U.S. West Coast fishing vessels observed by the NWFSC Fisheries Observation Science Program, 2002–19. MMPA and ESA status relates only to those populations in waters off the coasts of WA, OR, and CA. Numbers are numbers of individuals. *M/SI* = mortality/serious injury.

		Conservation status			Observed		
Common name	**Scientific name**	**MMPA**	**ESA**	**IUCN**	**M/SI**	**Interactions**	**Sightings**
California sea lion	*Zalophus californianus*	Protected	Not Listed	Least Concern	294	1,700	441
Steller sea lion	*Eumetopias jubatus*	Protected	Not Listed	Near Threatened	163	3,148	234
Northern fur seal	*Callorhinus ursinus*	Protected	Not Listed	Vulernable	2	9	115
Guadalupe fur seal	*Arctocephalus townsendi*	Depleted, Strategic	Threatened	Least Concern	0	1	0
Harbor seal	*Phoca vitulina*	Protected	Not Listed	Least Concern	12	60	13
Northern elephant seal	*Mirounga angustirostris*	Protected	Not Listed	Least Concern	45	5	3
Sea otter	*Enhydra lutris*	Depleted, Strategic	Threatened*	Endangered	0	1	48

*Southern subspecies (*Enhydra lutris nereis*) only.

1.1.2 Endangered Species Act (ESA)

The ESA was passed in 1973 to protect and recover imperiled species and the ecosystems upon which they depend (ESA 1973). A species is added to the list[1] when it has been deemed to meet the definition of endangered or threatened. Currently there are over 1,400 species[2] in the United States listed under the ESA. NMFS has jurisdiction over 80 endangered and 85 threatened marine species. Thirty-eight of these species[3] (or distinct populations of these species) occur along the U.S. West Coast, including eight whales (blue, fin, gray, humpback, killer, Northern Pacific right, sei, and sperm), one seal (Guadalupe fur), and the western distinct population segment of the Steller sea lion, which only occurs in the Alaska region (Tables 2 and 3). A portion of the eastern population of Steller sea lion occurs along the Washington, Oregon, and California coasts, but this population is not listed under the ESA. The U.S. Fish and Wildlife Service has jurisdiction over one listed marine mammal subspecies that occurs along the U.S. West Coast: southern sea otters. The Washington stock of northern sea otter subspecies occurs off the Washington coast, but this population is not listed under the ESA. Once a species is listed under the ESA, protective measures are authorized, which include restrictions on taking, transporting, or selling specimens, as well as protections for critical habitat.

1.1.3 International Union for the Conservation of Nature's Red List

The International Union for the Conservation of Nature's (IUCN) Red List of Threatened Species[4] is a comprehensive indicator of the species of conservation concern. Of the over 134,000 species that have been assessed, 37,000 species are threatened with extinction, including 26% of the assessed mammals (IUCN 2021). The IUCN Red List status for a species can be one of several categories, including: "least concern," "near threatened," "vulnerable,"

[1] https://go.usa.gov/xzD5f
[2] https://www.fws.gov/program/endangered-species/species
[3] https://go.usa.gov/xzD57
[4] https://www.iucnredlist.org/

"endangered," "critically endangered," "extinct in the wild," and "extinct." Categories are based on comprehensive review of available data by subject matter experts (IUCN 2021). None of the marine mammal species in this report have an IUCN status worse than endangered; however, a few species are considered "data deficient," meaning they have been assessed but there is not enough information available to make a status determination (IUCN 2021; Tables 2 and 3).

We present the IUCN Red List status, along with the MMPA and ESA status, of each marine mammal species observed as bycatch (i.e., a mortality or serious injury), a non-lethal interaction, or a sighting, in the U.S. West Coast groundfish fisheries (see Section 2 for more information on the types of marine mammal data collected by observers and the determination of injury severity). The MMPA status provides a snapshot of the population within U.S. waters. The ESA status provides additional layers of protection over the MMPA, but is designed to complement the MMPA, not replace it. The IUCN Red List status provides a global view of the conservation status of the species (Tables 2 and 3).

1.2 U.S. West Coast Groundfish Fisheries Management

The U.S. West Coast groundfish fisheries are multispecies fisheries that utilize a variety of gear types (Tables A-1–A-3 in Appendix A). These fisheries harvest species listed in the Pacific Coast Groundfish Fishery Management Plan (FMP; PFMC 2020) or incidentally catch FMP groundfish in pursuit of nongroundfish target species. These fisheries are managed by the Pacific Fishery Management Council (PFMC) in collaboration with the states of Washington, Oregon, California, and Idaho, and other stakeholders as well as tribal nations. Over 90 species are listed in the groundfish FMP, including a variety of rockfish, flatfish, roundfish, skates, and sharks. These species are found in both federal (>5.6 km offshore) and state waters (0–5.6 km offshore). Groundfish are both targeted and caught incidentally by trawl nets, hook-and-line gear, and fish pots.

Under the FMP, the groundfish fisheries consist of four management components:

1. The limited entry (LE) component encompasses all commercial fishers who hold a federal limited entry permit. The total number of LE permits available is restricted. Vessels with an LE permit are allocated a larger portion of the total allowable catch for commercially desirable species than vessels without an LE permit.
2. The open access (OA) component encompasses commercial fishers who do not hold a federal LE permit. Some states require fishers to carry a state-issued permit for certain OA sectors.
3. The recreational component includes recreational anglers who target or incidentally catch groundfish species. Recreational fisheries are not observed by NWFSC and therefore are not covered by this report.
4. The tribal component includes native commercial fishers from Washington State that have treaty rights to fish groundfish. Tribal fisheries are not included in this report, with the exception of the observed tribal at-sea Pacific hake (*Merluccius productus*, also known as whiting) sector.

These four components are further subdivided into sectors based on gear type, target species, permits, and other regulatory factors (Appendix A).

In 2011, the LE bottom trawl fishery of the U.S. West Coast groundfish fishery began fishing under an individual fishing quota (IFQ) management program. An IFQ is defined as a federal permit under a limited access system to harvest a quantity of fish, representing a portion of the total allowable catch of a fishery that can be received or held for exclusive use by a person (MSA 2006). The implementation of the IFQ management program in 2011 resulted in a mandate that vessels must carry NMFS observers or electronic monitoring (EM) equipment on all IFQ fishing trips. Prior to the IFQ program, vessels in this fishery could only fish with bottom trawl gear. Since the IFQ implementation, bottom and midwater trawl, as well as hook-and-line and pot gears, are allowed to be fished under this permit.

1.3 Fisheries Observation Science Program

The NWFSC Fisheries Observation Science Program (FOS) places at-sea observers on vessels in commercial fisheries that catch groundfish as target species or bycatch in the U.S. West Coast EEZ. At-sea observer data inform independent estimates of the amount and types of species caught and discarded in these fisheries. FOS has two units which observe distinct sectors of the groundfish fishery: the At-Sea Hake Observer Program (A-SHOP) and the West Coast Groundfish Observer Program (WCGOP; Tables A-1–A-3). Descriptions of the units and their associated fishery sectors can be found in Appendix A. Observer coverage rates are provided in Somers et al. (2021).[5] Fishing effort in each fishery sector FOS observes is provided in Somers et al. (2022b).

In this report, we use a combination of NWFSC groundfish observer data and EM and fish ticket data from the Pacific States Marine Fisheries Commission (PSMFC) to estimate marine mammal bycatch in U.S. West Coast groundfish fisheries during 2002–19.

[5] Somers, K. A., J. E. Jannot, K. E. Richerson, V. J. Tuttle, and J. T. McVeigh. 2021. Fisheries Observation Science Program Coverage Rates, 2002–20. U.S. Department of Commerce, NOAA Data Report NMFS-NWFSC-DR-2021-02. DOI: 10.25923/9rpa-9t92

2 Methods

2.1 Data Sources

Data sources for this analysis include on-board observer data from A-SHOP and WCGOP, landing receipt data (referred to as fish tickets), and EM data. Fish ticket data were obtained from the Pacific Fisheries Information Network (PacFIN), managed by PSMFC, and EM data were obtained from PSMFC.

2.1.1 NWFSC observer data

A list of fisheries, coverage priorities, and data collection methods employed by WCGOP in each observed fishery can be found in the WCGOP training manual (NWFSC 2021b). A-SHOP information and documentation on data collection methods can be found in the A-SHOP sampling manual (NWFSC 2021a).

The sampling protocol employed by WCGOP primarily focuses on the discarded portion of catch. To ensure that the recorded weights for the retained portion of the observed catch are accurate, haul-level retained catch weights recorded by observers are adjusted based on trip-level fish ticket records. This process is described in detail in the annual groundfish mortality report (Somers et al. 2022a) and on the FOS web page.[6] The A-SHOP sampling protocol includes both the retained catch as well as the discarded portion of catch. Data processing was applied prior to the analyses presented in this report.

2.1.1.1 Observer sampling for marine mammals

Marine mammal interactions take priority over all other observer duties. For the purposes of bycatch estimation, we assume that any observed marine mammals represent a complete census of the mammals in the observed catch. This assumption is justified because the large size of marine mammals makes them easy to observe and sample, even when found among large quantities of fish catch.

Observers must record all interactions between mammals and fishing vessels and identify each marine mammal to species or the lowest possible taxonomic unit. Observers are instructed to take multiple photographs of the individual, collect any tag information and, for freshly dead or seriously injured individuals, when possible, record length, sex, and collect a tissue sample (NWFSC 2021a,b). Tissue samples from pinnipeds are used to verify genetic species identification using conserved markers to amplify fragments of the mitochondrial genome (Kocher et al. 1989, Carr and Marshall 1991). Any marine mammal tag information is collected and delivered to NOAA's West Coast Marine Mammal Stranding Network.

[6] https://go.usa.gov/xzDwh

Observers must prioritize data collection and documentation of any lethal or injurious interactions over nonlethal interactions. Interactions of all types are prioritized over sightings (i.e., animal does not interact with vessel or vessel outputs). Observations of nonlethal interactions and sightings at the fishing grounds are prioritized over those observations made at the dock or during transit. Nonlethal interactions and sightings are considered to be opportunistic observations because systematic random sampling of these events is not conducted. Opportunistic observations are most likely an underestimate, especially for commonly sighted species (e.g., California sea lion, Steller sea lion).

Observers record a variety of lethal and nonlethal fishery interactions with marine mammals. Both observer programs use a system of coded categories to document interactions.

Table 4. Descriptors used by fishery observers to categorize types of marine mammal interactions with U.S. West Coast groundfish fisheries fishing vessels.

Category	Description
Lethal Removal—Not Trailing Gear	Animal(s) killed by vessel personnel to prevent serious damage to or loss of gear, catch, or human life. No gear attached to animal(s) when returned to sea.
Lethal Removal—Trailing Gear	Animal(s) killed by vessel personnel to prevent serious damage to or loss of gear, catch, or human life. Pieces of gear, including parts of net or line, attached to animal(s) when returned to sea.
Killed by Gear	Animal(s) killed by interaction with gear.
Vessel Strike	Animal(s) struck by some part of the vessel, including hull, mast, rigging, or cables.
Entangled in Gear—Not Trailing Gear	Animal(s) entrapped or entangled in fishing gear, but escape or are released alive. Includes instances where an individual is hooked. No gear attached to animal(s) when returned to sea.
Entangled in Gear—Trailing Gear	Animal(s) entrapped or entangled in fishing gear, but escape or are released alive. Includes instances where an individual is hooked. Pieces of gear, including parts of net or line, attached to animal(s) when returned to sea.
Feeding on Bait—Attached to Hook	Animal(s) feeding on bait that is still attached to hooks.
Feeding on Bait—Floating Free	Animal(s) feeding on bait that has come free of gear.
Feeding on Discarded Catch	Animal(s) feeding on any part of discarded catch.
Feeding on Offal	Animal(s) feeding on the discarded products of fish processing (e.g., fish guts).
Feeding on Catch	Animal(s) feeding on fish prior to the fish being brought on vessel.
Foraging, Not Bait	Animal(s) foraging or feeding near the vessel but not feeding on bait or discards. (A-SHOP only.)
Deterrence Used	Vessel personnel attempted to deter interaction with animal(s) using: firearm, gaff, acoustic device, yelling, or other method.
Boarded Vessel	Animal(s) boarded fishing vessel of own volition.
Unknown	Vessel or vessel personnel interacted with animal(s), but observer did not directly view interaction nor ascertain what interaction was. Observer notes describe interaction details, when possible.
Other	Animal(s) involved in interactions with vessel; however, interaction type is not included in list of interaction codes. Observer notes describe interaction details, when possible.
Sighting Only	Animal(s) did not interact with vessel, but animal(s) were within observation distance of vessel and/or observer.

Interactions need to be screened for inclusion (or exclusion) from bycatch estimation, as not all interactions lead to injury or mortality. To aid this process, in 2015, WCGOP instituted a protocol to record one of five possible outcomes of the interaction:

1. *Alive—No visible signs of injury*: Individual(s) alive and showing no visible signs of injury because of the interaction.
2. *Alive—Visible signs of injury*: Individual(s) alive, but showing signs of injury that might be a result of the interaction.
3. *Dead or Unresponsive Carcass*: Individual(s) dead or unresponsive.
4. *Not Applicable*: Code only used for sightings.
5. *Unknown*: Observer is unsure of outcome. Observer notes describe interaction details, when possible.

A-SHOP observers record one of eight possible conditions based on the outcome of the interaction. A live animal that has been lethally removed is considered a carcass; however, an injured animal released alive is considered alive even if the observer believes it may eventually die due to those injuries (AFSC 2021). If the condition of the mammal was recorded as "live animal," observers document all potential injuries, if any injuries are present, or note the absence if no injuries are present or suspected (AFSC 2021).

1. *Carcass, dead animal.*
2. *Bones other than skull.*
3. *Live animal.*
4. *Skull.*
5. *Skull and bones.*
6. *Tusk/teeth (no skull).*
7. *Baleen only.*
8. *Fur, flesh, or skin.*

2.1.2 Fish ticket data

For total fleetwide (observed + unobserved) bycatch estimation, the landed amount of each species or species group is the only proxy for effort measured for the entire fleet. Thus, the retained landing information from sales receipts (known as fish tickets) is crucial for fleetwide total bycatch estimation for the shoreside-processed commercial groundfish fisheries on the U.S. West Coast that do not have 100% observer coverage or electronic monitoring. Fish tickets are trip-aggregated sales receipts for market categories that may represent single or multiple species. Fish ticket landing receipts are completed by buyers in each port for each delivery of fish by a vessel. Fish tickets are issued to buyers by a state agency and must be returned to the issuing agency for processing. Fish tickets are designed by the individual states (Washington, Oregon, and California) with slightly different formats by state. In addition, each state conducts species-composition sampling at the ports for numerous market categories that are reported on fish tickets. Fish ticket and species-composition data are submitted by state agencies to the PacFIN regional database.

Annual fish ticket landings data, with state species composition sampling applied, were retrieved from the PacFIN database and subsequently divided into various sectors of the groundfish fishery. Observer and fish ticket data processing steps are described in detail in the annual groundfish mortality report (Somers et al. 2022a, Appendix B). All data processing steps specific to this report are described in Section 2.3.

2.2 Serious Injury and Mortality Determinations

Under the MMPA, a "take" is defined as any act that harasses, hunts, captures, kills, or attempts to harass, hunt, capture, or kill, a marine mammal. While commercial fisheries are granted an exemption on the prohibition of takes under the MMPA, the Act tasks NMFS with managing serious injuries and mortalities of marine mammals from bycatch in commercial fishing operations. NMFS has established guidelines for distinguishing serious from nonserious injury of marine mammals pursuant to the MMPA through a policy directive and instruction (Andersen et al. 2008, NMFS 2012a,b). A serious injury is any injury that is "more likely than not" to result in mortality, or any injury that presents a greater than 50% chance of death to a marine mammal. Thus, serious injuries can include cases where an animal initially survives, but later dies or is expected to die as a consequence of the injury (NMFS 2012a).

Serious injury and mortality designations were determined by marine mammal injury experts at NOAA's Southwest Fisheries Science Center (La Jolla, California) and Alaska Fisheries Science Center Marine Mammal Laboratory (Seattle; Carretta et al. 2020a, Young et al. 2020). The combination of the interaction category, interaction outcome or condition, and specific details in observer notes—and, when available, photographs and video recorded at the time of the interaction—informed injury and mortality designations. For most interactions, the interaction category, in combination with the interaction outcome or condition, was sufficient to make the determination. Observers typically detail the nature of the injury and any changes in the animal's behavior following its release. Noted factors indicating a potential mortality or serious injury could include evidence of bleeding, broken bones, wounds, trailing gear, vomiting, and abnormal behavior. In the cases of live but potentially injured animals, NOAA and NMFS guidelines and policies were applied to determine whether the injury had the potential to cause mortality, was serious, or was nonserious (NMFS 2012b, Carretta et al. 2020a, Young et al. 2020). Serious injuries and mortalities were used in bycatch estimates, whereas nonserious injuries or other nonlethal interactions were excluded from bycatch estimates and are reported here as nonlethal interactions.

2.3 Bycatch Estimation

Estimates of bycatch are only made for fisheries with less than 100% observer coverage or less than 100% electronic monitoring. In the cases of 100% monitoring by either a human or EM, we assume a complete census of marine mammal bycatch, as described above. Crew are required to display all marine mammal bycatch to human observers or, when EM is used, to the EM cameras.

Even though ratio estimators have been widely used in discard estimation (Stratoudakis et al. 1999, Borges et al. 2005, Walmsley et al. 2007), including in the U.S. West Coast fisheries (e.g., Jannot et al. 2011), ratio estimators are known to make restrictive assumptions and can be biased, especially when bycatch events are rare (Rochet and Trenkel 2005, Carretta and

Moore 2014, Martin et al. 2015). Ratio estimators rely heavily on the assumption that bycatch is proportional to some metric or proxy of fishing effort, such as fishery landings, an assumption not often supported by data (Rochet and Trenkel 2005). In some cases, bycatch might vary nonlinearly or even be unrelated to the ratio estimator denominator. Most mammal species reported here are rarely caught. The rarity of marine mammal bycatch, combined with less than 100% observer monitoring in many of these fisheries, makes it difficult to assess the link between marine mammal bycatch and fishing effort. Low levels of observer coverage can produce biased estimates when ratio estimators are used to calculate fleetwide bycatch of protected species (Carretta and Moore 2014, Martin et al. 2015).

2.3.1 Bayesian model

2.3.1.1 Statistical model

We applied Bayesian models to observer program data to estimate marine mammal bycatch and characterize uncertainty in those estimates, and applied models within each fishery with less than 100% monitoring. These methods have been used with other rare bycatch species, including cetaceans, delphinids, pinnipeds, sea turtles, sharks, and seabirds (Martin et al. 2015, Jannot et al. 2018, 2021). For each model, there are three parameterization choices to be made:

1. The effort metric on observed vessels, of which there are three possible choices: number of gear deployments, number of gear units, or mass of landed catch (as weight in metric tons [mt]).
2. The type of bycatch rate: constant rate, or time-varying rate.
3. The type of bycatch-generating process: Poisson, or negative binomial.

In this report, we formally compare all combinations of the three potential effort metrics, two potential bycatch rates, and two possible bycatch-generating models. We use methods from the R package `loo` (Vehtari et al. 2020), which uses Stan (Stan Development Team 2021) as implemented in the R package `bycatch` (Ward and Jannot 2021), to compare among models within each fishery–species–gear type. Final estimates are presented from the single model that best fits the data.

For each fishery, the base model assumed bycatch rate was constant, and inferred annual expected mortality, conditioned on fishing effort, using a simple Poisson process model (Martin et al. 2015), where the total number of bycatch events was assumed to follow a Poisson distribution,

$$n_{take,y} \sim (\lambda_y = \theta \times E_y)$$

where:

$n_{take,y}$ = number of observed bycatch events (a.k.a. takes[7]) in the year,
λ_y = expected observed bycatch,
θ = estimated observed bycatch rate, and
E_y = observed effort in the year.

The estimated bycatch rate, θ, is assumed constant through time in the base model, but the quantity $\theta \times E_y$ includes uncertainty because θ is estimated. Thus, a time series of the expected observed bycatch can be generated for a given species, with a given metric of effort. Fluctuations in fishing effort through time then result in year-to-year variability (percent observer coverage only affects the expansion). We used a Bayesian implementation of this model (Martin et al. 2015) to generate mean and 95% credible intervals (CIs) of the bycatch rate parameter, θ, as well as for the expected bycatch in the observed portion of the fleet, $\theta \times E_y$. For more information regarding distributions and implementation in R and Stan, please see the articles in the R `bycatch` package (Ward and Jannot 2021).

We built upon the simplified model above with the goal of finding the model that most accurately estimates bycatch and variance. To do that, we compared models to: a) find the most suitable effort metric, b) test the assumption that θ is constant through time, and c) compare distributions (Poisson and negative binomial). Though our code allows for the inclusion of covariates, which can vary through time, we only considered time-varying models that treat bycatch rate as a random walk (in log space), $\theta_y \sim Normal(\theta_{y-1}, \sigma_\theta)$, where σ_θ is an estimated parameter controlling the year-to-year variability.

2.3.1.2 Model diagnostics and selection

Before comparing among models, each model must be tested for efficacy using Pareto-K values. The `loo` package (Vehtari et al. 2020) implements leave one out (LOO) sampling, a form of cross validation based on Pareto smooth importance sampling (PSIS). Theoretically, the PSIS should converge to a mean and variance for the distribution. However, due to the use of random variables, convergence does not always emerge. LOO sampling generates a Pareto-K value that reflects its convergence properties. General rules of thumb for evaluating the Pareto-K statistics are that "low" Pareto-K values ($K < 0.5$) indicate convergence of the mean and variance, "slightly high" Pareto-K values ($0.5 \leq K < 1$) indicate a model whose variance either does not converge at all or converges slowly, and "high" Pareto-K statistics ($K > 1$) indicate that neither the mean nor the variance converges (Vehtari et al. 2019).

In addition to Pareto-K values, LOO can be used to test for overparameterization by generating a p-LOO value that is compared to the number of parameters used in the model. The parameters for the model include all the incorporated covariates, as well as time, effort, and distribution. A p-LOO less than the number of parameters denotes an appropriately parameterized model.

[7] As noted in Section 2.2, only mortalities and serious injuries were included in bycatch estimates. With respect to the bycatch estimates or description of the bycatch estimation process in this report, "take" means serious injuries and mortalities.

Once a model is considered suitable, the optimal model can be chosen by comparing among leave one out information criteria (LOOIC). For each fishery, there are a total of 12 possible models (three effort metrics, two rates, two distributions). Leave one out cross validation (LOOCV) is a widely used tool to identify models with good predictive ability; this can be done in a Bayesian framework, but could be slow depending on the number of folds used. As an alternative, the R package `loo` approximates LOOCV by implementing LOO sampling, which tests the efficacy of the model based on its predictive ability for new data (Vehtari et al. 2020). Importance sampling is typically used when multiple distributions may be present, or when the density of the distribution is only partially known (Vehtari et al. 2019). Like more familiar model selection criteria, such as the Akaike information criterion (AIC), the preferred model is the model with the lowest LOOIC estimate.

The 12 models within a fishery were tested in the following order and excluded if any of the following cases were met:

1. Pareto-K > 0.7 (as suggested by Vehtari et al. [2019]).
2. p-LOO > 3 (the number of parameters).
3. LOOIC is not the minimum.

In some combinations of fishery–species–gear, all 12 models failed both the Pareto-K and p-LOO tests. To reduce the model complexity and obtain estimates of bycatch in these cases, we reverted to the base model (constant bycatch rate and Poisson distribution, as described above), compared among effort metrics, and chose the single model that minimized all three model diagnostics, even if those diagnostics were larger than recommended. The final model specifications for each species, by fishery and gear type, are given in Supplemental Table 38.

For information about the sensitivity of the models to model and data assumptions, please see Jannot et al. (2021).

2.3.2 Expanding bycatch to unobserved portion of fleet

Because observer coverage is less than 100% in some fishing sectors, and variable through time, we need to expand the estimated bycatch in the observed portion of each fleet, $\theta \times E_y$, to the entire fleet, which includes unobserved vessels. One approach for expansion would be to divide $\theta \times E_y$ by the percent observer coverage; however, this ignores uncertainty in the expansion. We accounted for uncertainty in the expansion by estimating the posterior predictive distribution of unobserved takes, given unobserved effort and estimated parameters:

$$P(Y^*|Y) = \int_{\theta} P(Y^*|\theta,Y)P(\theta|Y)d\theta$$

where

Y^* = estimated bycatch,
Y = observed bycatch, and
θ = bycatch rate.

We subtracted the observed effort from the total effort to obtain the unobserved effort. We used these simulated posterior predictive values to generate 95% CIs for the predicted total bycatch in each year (adding observed bycatch to the posterior predictive distribution of unobserved bycatch). Details on the implementation of this in R can be found in the `bycatch` package (Ward and Jannot 2021). Fleetwide bycatch was estimated for each sector using observer coverage data (Somers et al. 2021).

2.4 Statistical Software

The statistical software R (v4.1.2; R Core Team 2021) was used to produce the analyses, tables, and figures in this report. Specifically, we relied heavily on the R packages `bycatch` (Ward and Jannot 2021) for modeling and simulation, `ggplot2` (Wickham 2016) for plotting figures, `loo` (Vehtari et al. 2020) for model diagnostics and comparisons, `knitr` (Xie 2021) for tables and dynamic reporting, and `tidyverse` (Wickham et al. 2019) for data wrangling.

3 Results and Discussion

In this report, we applied a Bayesian modeling approach to estimate total bycatch and associated variability for fisheries with less than 100% observer monitoring, similar to Jannot et al. (2018, 2021). Similar methods have been used with other rare bycatch species, including cetaceans, delphinids, pinnipeds, sea turtles, and sharks (Martin et al. 2015, Jannot et al. 2021). We modeled bycatch rate and inferred annual expected mortality and associated uncertainty, given a specified level of effort. All estimates for fisheries with less than 100% monitoring reported in the tables below are based on the Bayesian estimates (±95% CIs). For fisheries with 100% human or EM monitoring, numbers of animals in the tables represent a complete census of individuals.

3.1 Total Marine Mammal Bycatch

Overall, pinnipeds are caught and injured or killed in higher numbers than cetaceans in U.S. West Coast groundfish fisheries (Figures 1–3). Among pinnipeds, California sea lions are the most frequently caught species, with a peak of about 102 animals estimated bycaught in 2017, followed by Steller sea lions with a peak of about 32 animals estimated in 2016 (Table 5). On average, between two and five harbor seals and three to nine northern elephant seals are estimated to be caught each year, whereas northern fur seals are rarely caught, between zero and one animal per year. Every year an estimated one to three unidentified sea lions, otariids, or pinnipeds (combined) are caught (Table 5). The majority of pinniped bycatch occurs in and around San Francisco Bay and along the southern Oregon coast (Figure 4). A smaller amount of pinniped bycatch occurs in the northern portion of the Southern California Bight as well as along the Washington coast, particularly offshore and just south of Cape Flattery, Washington (Figure 4).

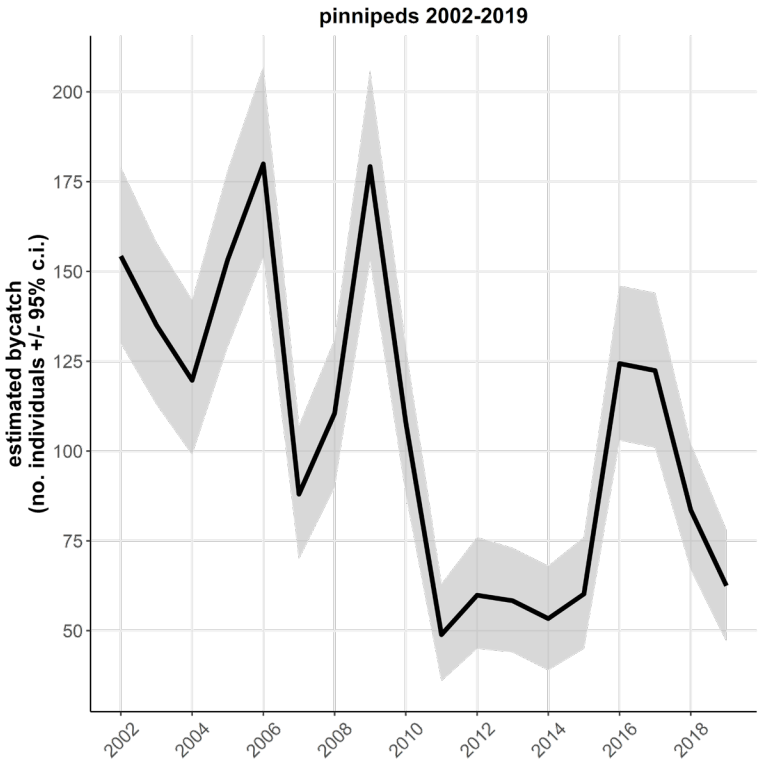

Figure 1. Annual estimated bycatch (number of individuals, 95% CI) of pinnipeds in U.S. West Coast groundfish fisheries, 2002–19.

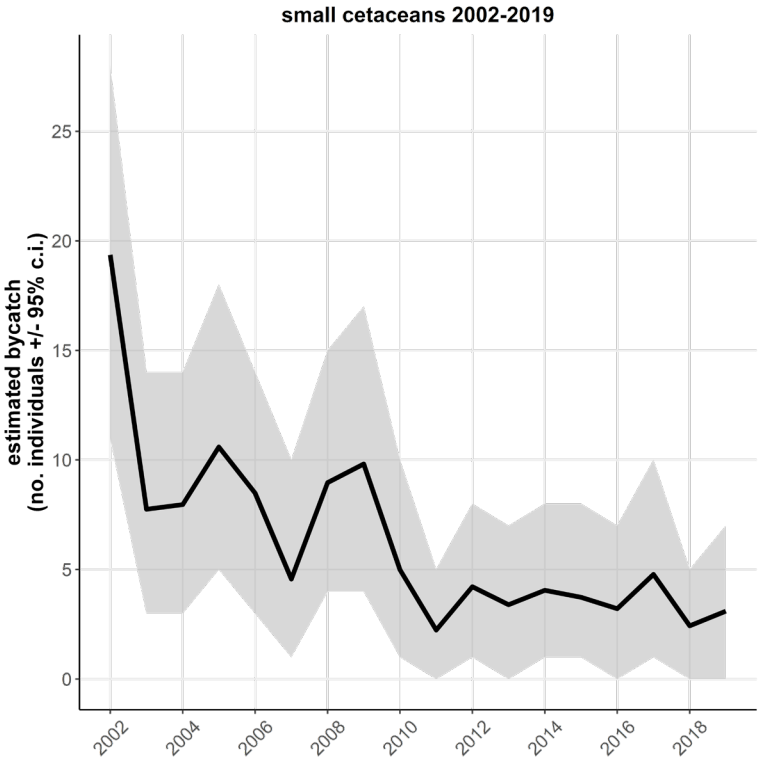

Figure 2. Annual estimated bycatch (number of individuals, 95% CI) of small cetaceans in U.S. West Coast groundfish fisheries, 2002–19.

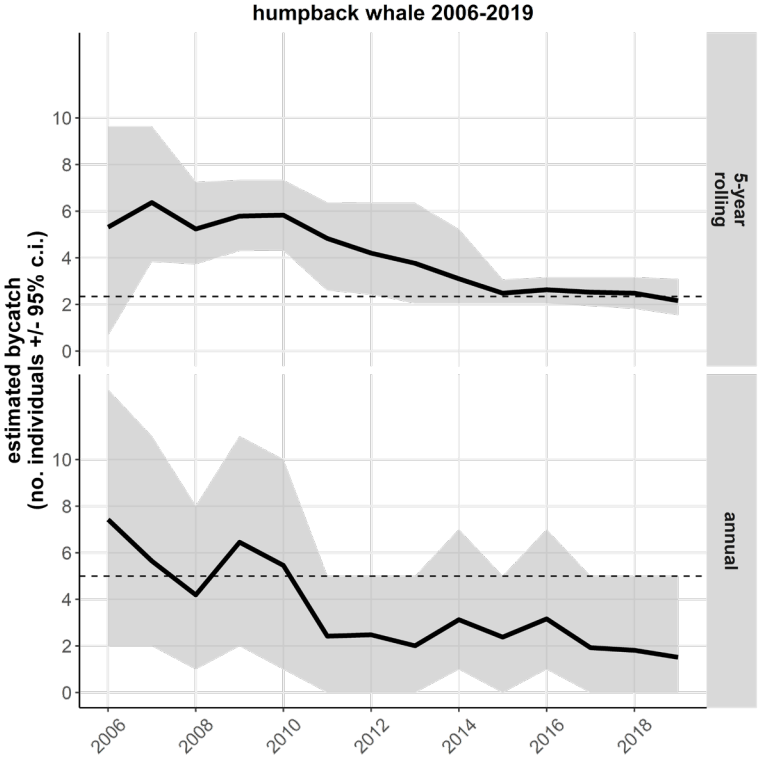

Figure 3. The 5-yr rolling average (top) and annual (bottom) estimated bycatch (number of individuals, 95% CI) of humpback whales in U.S. West Coast groundfish fisheries, 2002–19. Dotted line is the five-year running average threshold (top) or the annual threshold (bottom) for incidental take in the 2020 Biological Opinion (NMFS 2020). To date, humpback whales are the only large cetacean observed as bycatch in these fisheries.

Table 5. Estimated marine mammal mortality (95% CI) in U.S. West Coast groundfish fisheries, 2015–19. Estimates, 95% CIs, and coefficients of variation for each species and year in the entire time series can be found in the Supplemental Tables.

Species	2015	2016	2017	2018	2019
California sea lion	23.25 (14–33)	77.90 (61–96)	102.50 (83–122)	52.26 (38–67)	61.01 (46–77)
Common bottlenose dolphin	0.71 (0–3)	0.54 (0–3)	0.73 (0–3)	0.72 (0–3)	0.86 (0–3)
Dall's porpoise	0.00 (0–0)	0.00 (0–0)	0.00 (0–0)	0.00 (0–0)	0.00 (0–0)
Harbor seal	2.69 (0–7)	2.31 (0–5)	4.03 (1–8)	3.19 (0–7)	4.67 (1–10)
Humpback whale	1.55 (0–5)	2.45 (0–5)	1.47 (0–3)	1.19 (0–3)	1.16 (0–3)
Northern elephant seal	9.21 (4–15)	4.57 (1–10)	3.73 (1–8)	3.42 (0–7)	3.51 (1–8)
Northern fur seal	0.00 (0–0)	1.00 (0–3)	0.00 (0–0)	0.00 (0–0)	0.00 (0–0)
Northern right whale dolphin	0.00 (0–0)	1.00 (0–3)	0.00 (0–0)	0.00 (0–0)	0.00 (0–0)
Otariid, unidentified	0.00 (0–0)	0.00 (0–0)	0.00 (0–0)	0.00 (0–0)	0.00 (0–0)
Pacific white-sided dolphin	2.00 (0–5)	0.00 (0–0)	2.00 (0–5)	0.00 (0–0)	0.00 (0–0)
Pinniped, unidentified	1.86 (0–5)	0.74 (0–3)	0.91 (0–3)	0.89 (0–3)	1.04 (0–3)
Sea lion, unidentified	0.29 (0–0)	1.48 (0–3)	2.47 (0–5)	1.40 (0–3)	2.38 (0–5)
Steller sea lion	20.00 (12–29)	32.16 (21–44)	28.56 (19–40)	26.65 (17–38)	10.71 (5–18)

Cetaceans are generally rare in the bycatch of U.S. West Coast groundfish fishery vessels (Table 5), and bycatch events are widely dispersed from Cape Flattery to Point Arguello, California (Figure 5). Common bottlenose dolphin is the most frequently encountered cetacean in U.S. West Coast groundfish fishery bycatch, with one animal caught each year (Table 5). Several other species of cetaceans have been observed in the bycatch in very low amounts (approximately 0–2 per year), including Pacific white-sided and northern right whale dolphins and Dall's porpoise.

Humpback whales have been observed entangled in pot gear used in U.S. West Coast groundfish fisheries twice by WCGOP observers, once in 2014 and once in 2016. This has led to an estimate of about one humpback entanglement per year in 2017, 2018, and 2019 (Table 5, Figure 3). The estimated fleetwide takes were not above the five-year running average threshold (threshold = 2.34/year, estimated 5-yr average = 2.19; Figure 3) set by the Incidental Take Statement in the 2020 Biological Opinion (NMFS 2020).

Estimates for all species during the entire 2002–19 period are provided in Supplemental Table 2.

3.2 Trawl Fisheries

U.S. West Coast groundfish trawl fisheries, which include the at-sea hake, catch share trawl, California halibut, and California prawn fisheries, have caught and injured or killed both pinnipeds and small cetaceans as bycatch (Table 6). The overall trend of pinniped bycatch in trawl fisheries has been a general decline from an estimated 125 animals in 2002 to less than 50 estimated in 2019 (Figure 6). However, the downward trend has been punctuated by a number of notable peaks in pinniped bycatch—in 2006 (150 animals), 2009 (over 125 animals), and, after a period of <50 animals annually from 2011 to 2015, an uptick to about 100 animals in 2016, before dropping again (Figure 6). The uptick in 2016 was likely due, in part, to large numbers of pinnipeds caught in the at-sea hake fishery that year. The majority of bycatch in trawl fisheries consists of California sea lions and, to a lesser extent, Steller sea lions and a few northern elephant seals.

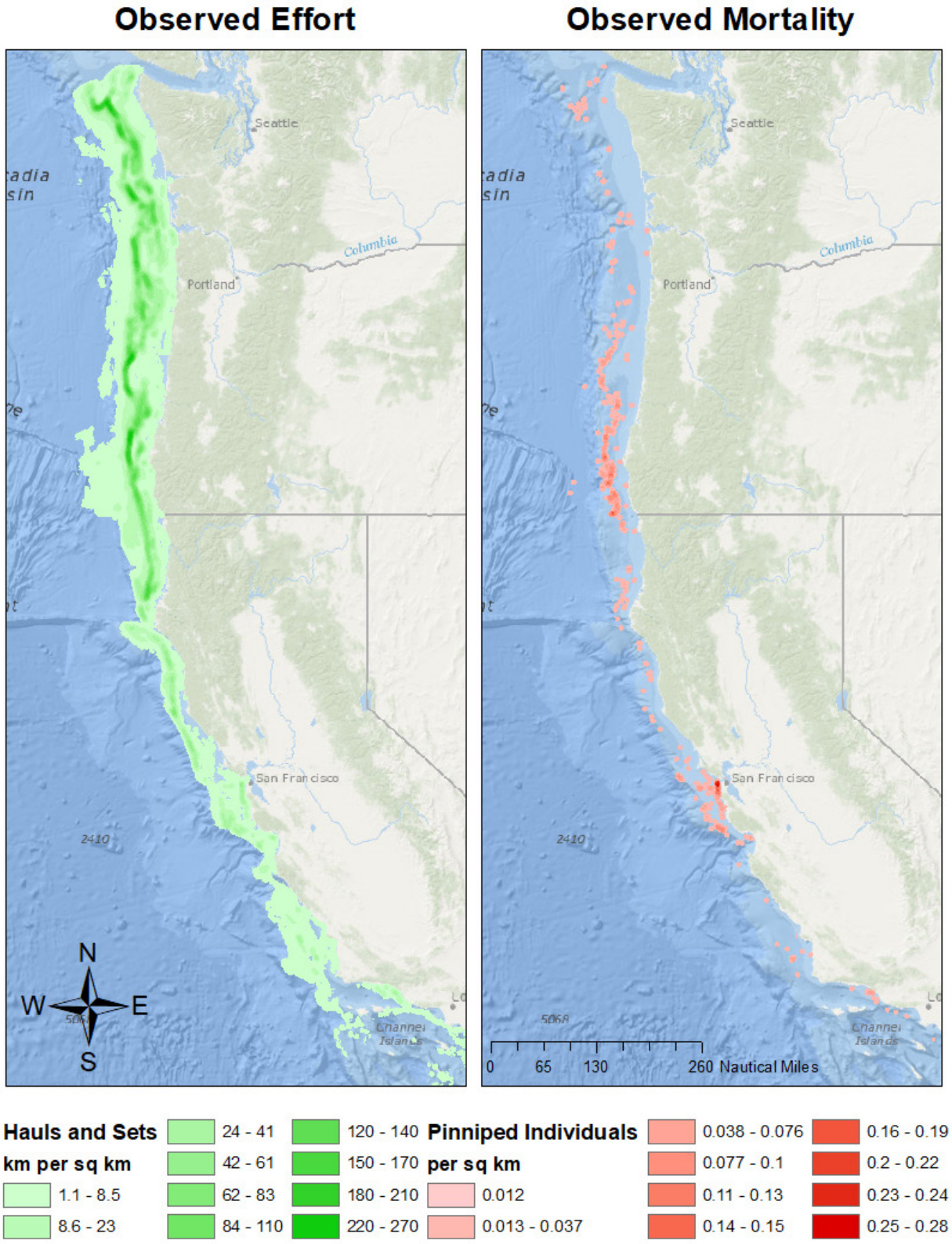

Figure 4. Spatial distribution of observed pinniped bycatch (individuals/km^2) and monitored fishing hauls and sets on vessels along the WA, OR, and CA coasts observed by FOS (2002–19) and the PSMFC EM program (2015–19). The 10 catch classifications were defined by excluding any zero values and then applying the Jenks natural breaks classification method. Cells (200 km^2) with <3 vessels were omitted to maintain confidentiality.

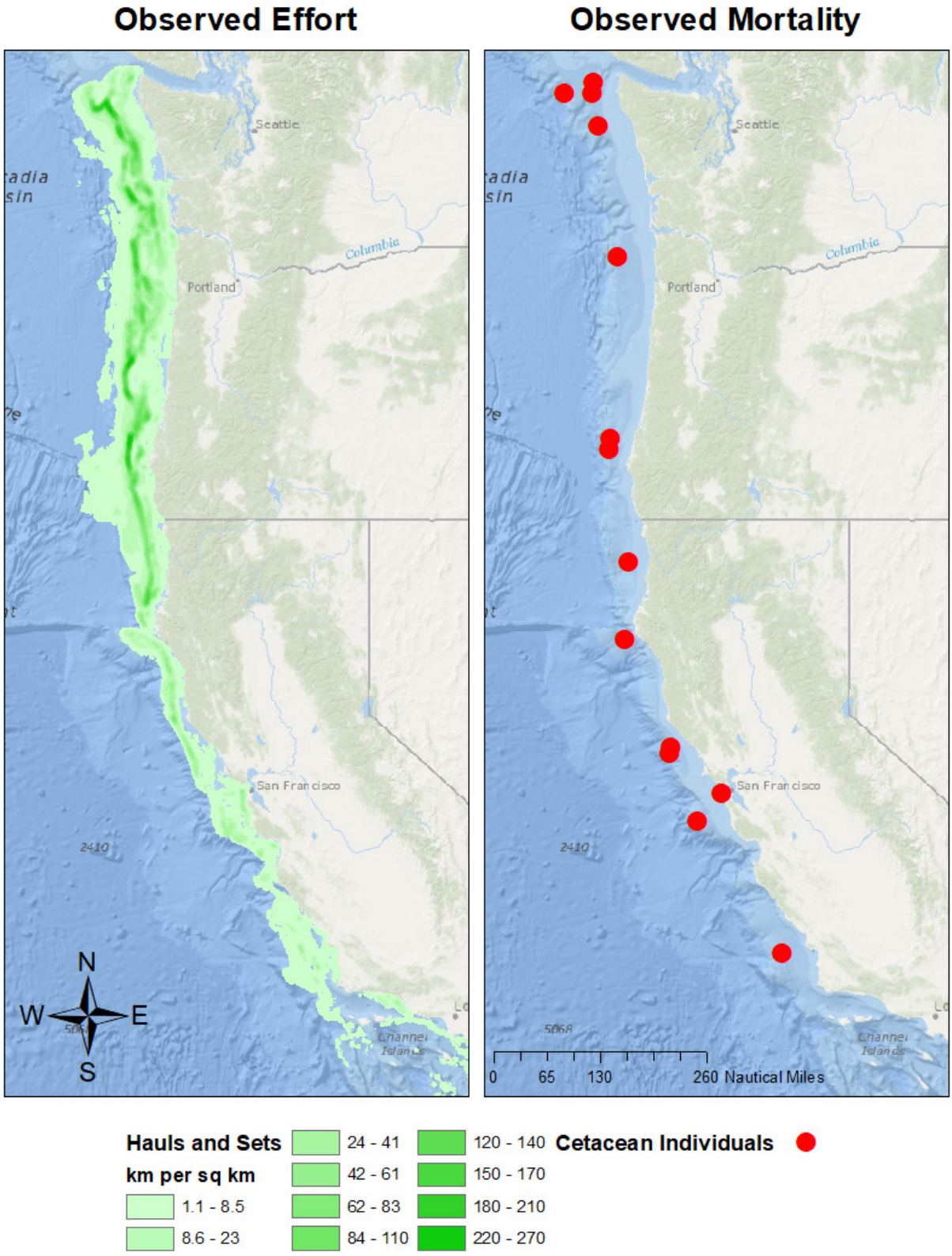

Figure 5. Spatial distribution of monitored fishing hauls and sets and observed cetacean bycatch (individuals) on vessels along the WA, OR, and CA coasts observed by FOS (2002–19) and the PSMFC EM program (2015–19). The 10 catch raster classifications for fishing effort were defined by excluding any zero values and then applying the Jenks natural breaks classification method. Cells (200 km^2) with <3 vessels were omitted to maintain confidentiality. Cetacean bycatch is too sparse to apply raster techniques; therefore, we added a small amount of random noise to the points to maintain the confidentiality of catch locations.

Table 6. Estimated marine mammal mortality (95% CI) among the U.S. West Coast groundfish fishery vessels fishing with trawl gears, 2015–19. Estimates, 95% CIs, and coefficients of variation for each species and year in the entire time series can be found in the Supplemental Tables.

Gear	Species	2015	2016	2017	2018	2019
Trawl	California sea lion	16.32 (9–24)	71.88 (56–89)	90.30 (72–109)	44.73 (32–59)	54.92 (41–70)
Trawl	Dall's porpoise	0.00 (0–0)	0.00 (0–0)	0.00 (0–0)	0.00 (0–0)	0.00 (0–0)
Trawl	Harbor seal	0.42 (0–0)	0.59 (0–3)	2.11 (0–5)	0.80 (0–3)	1.95 (0–5)
Trawl	Northern elephant seal	5.22 (1–10)	3.32 (0–7)	2.61 (0–7)	0.44 (0–0)	1.52 (0–5)
Trawl	Northern fur seal	0.00 (0–0)	1.00 (0–3)	0.00 (0–0)	0.00 (0–0)	0.00 (0–0)
Trawl	Northern right whale dolphin	0.00 (0–0)	1.00 (0–3)	0.00 (0–0)	0.00 (0–0)	0.00 (0–0)
Trawl	Otariid, unidentified	0.00 (0–0)	0.00 (0–0)	0.00 (0–0)	0.00 (0–0)	0.00 (0–0)
Trawl	Pacific white-sided dolphin	2.00 (0–5)	0.00 (0–0)	2.00 (0–5)	0.00 (0–0)	0.00 (0–0)
Trawl	Sea lion, unidentified	0.00 (0–0)	1.00 (0–3)	2.00 (0–5)	1.00 (0–3)	2.00 (0–5)
Trawl	Steller sea lion	19.80 (12–29)	29.82 (20–41)	28.21 (18–39)	26.38 (17–36)	10.44 (4–17)

Small cetacean bycatch was slightly more than an estimated 10 animals in 2002, and steadily declined to zero in 2011 to 2013 before climbing again to one or two animals during the 2014 to 2017 period, and then dropping to zero in 2018 and 2019 (Figure 6).

During the 2014 to 2017 period, the small cetacean species in the bycatch were Pacific white-sided dolphins and northern right whale dolphins, both in very low numbers (1-2 animals per year; Table 6, Figure 6).

The entire time series of trawl fishery estimates for both pinnipeds and cetaceans is provided in Supplemental Table 3.

Historically, no bycatch interactions between large cetaceans and U.S. West Coast groundfish fishery trawl vessels have been documented by fishery observers. However, in 2020, two humpback whales were observed entangled in the midwater trawl net of two midwater hake vessels carrying EM equipment. Based on review of the available data, in both cases, the humpback whales were thought to be dead at the

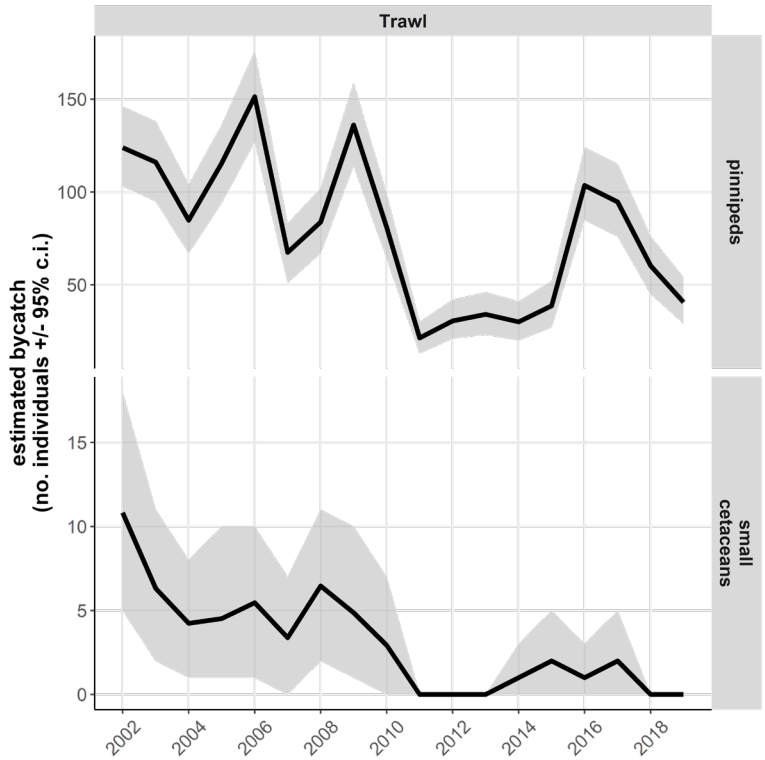

Figure 6. Annual estimated bycatch (number of individuals, 95% CIs) of pinnipeds and small cetaceans in U.S. West Coast groundfish trawl fisheries, 2002–19.

time the net was retrieved. These determinations were based on reports from vessel crew as well as review of the EM video footage. Both of the captains from the two vessels reported that, in each case, the whale was in poor or dead condition prior to entanglement in the trawl. In one of the scenarios, multiple buoys used in fixed gear fisheries were observed in the EM video, suggesting that, in this case, the whale might have been previously entangled and therefore already dead or in poor condition, making it susceptible to capture within the trawl net. In both cases, the EM video is useful but has not provided a definitive evaluation of either animal's condition. Multiple SWFSC and Marine Mammal Stranding Program staff reviewed the EM video, but could not determine whether the whales were dead or alive at the time of capture. NMFS will continue to evaluate the evidence (NMFS 2020).

3.2.1 At-sea hake fishery

The at-sea hake sector has 100% monitoring and, because marine mammals are large and crew are expected to report all marine mammal bycatch to the fishery observers, these vessels have a complete census of mammal bycatch. California and Steller sea lions are the most frequently caught pinnipeds in the at-sea hake fishery, on both the catcher–processors and the catcher vessels delivering to motherships (Tables 7 and 8, Figure 7). Both vessel types also occasionally entangle harbor and northern elephant seals. Catcher vessels have also taken northern fur seals and unidentified otariids (Tables 7 and 8, Figure 7). Both vessel types have taken Pacific white-sided dolphins. Catcher vessels delivering to motherships have also taken Dall's porpoise and northern right whale dolphins. The entire time series of at-sea hake fishery estimates for both pinnipeds and cetaceans is provided in Supplemental Tables 4 and 5.

Table 7. Estimated marine mammal mortality among the U.S. West Coast at-sea hake catcher–processor (CP) vessels fishing with midwater trawl (MT) gears, 2015–19. Because vessels in this fishery are monitored 100%, we assume that error around the values presented here is zero (0), so confidence intervals and coefficients of variation are not estimated.

Sector	Gear	Species	2015	2016	2017	2018	2019
At-sea hake CP	MT	California sea lion	0.00	49.00	21.00	5.00	6.00
At-sea hake CP	MT	Harbor seal	0.00	0.00	0.00	0.00	0.00
At-sea hake CP	MT	Northern elephant seal	1.00	1.00	0.00	0.00	1.00
At-sea hake CP	MT	Pacific white-sided dolphin	0.00	0.00	1.00	0.00	0.00
At-sea hake CP	MT	Steller sea lion	0.00	21.00	1.00	4.00	0.00

Table 8. Estimated marine mammal mortality among the U.S. West Coast at-sea hake catcher vessels (CV) delivering to motherships and fishing with midwater trawl (MT) gears, 2015–19. Because vessels in this fishery are monitored 100%, we assume that error around the values presented here is zero (0), so confidence intervals and coefficients of variation are not estimated.

Sector	Gear	Species	2015	2016	2017	2018	2019
At-sea hake CV	MT	California sea lion	0.00	3.00	9.00	2.00	0.00
At-sea hake CV	MT	Dall's porpoise	0.00	0.00	0.00	0.00	0.00
At-sea hake CV	MT	Harbor seal	0.00	0.00	0.00	0.00	0.00
At-sea hake CV	MT	Northern elephant seal	1.00	0.00	2.00	0.00	0.00
At-sea hake CV	MT	Northern fur seal	0.00	1.00	0.00	0.00	0.00

Table 8 (continued). Estimated marine mammal mortality among the U.S. West Coast at-sea hake catcher vessels delivering to motherships and fishing with midwater trawl gears, 2015–19.

Sector	Gear	Species	2015	2016	2017	2018	2019
At-sea hake CV	MT	Northern right whale dolphin	0.00	1.00	0.00	0.00	0.00
At-sea hake CV	MT	Otariid, unidentified	0.00	0.00	0.00	0.00	0.00
At-sea hake CV	MT	Pacific white-sided dolphin	0.00	0.00	0.00	0.00	0.00
At-sea hake CV	MT	Steller sea lion	0.00	2.00	8.00	8.00	0.00

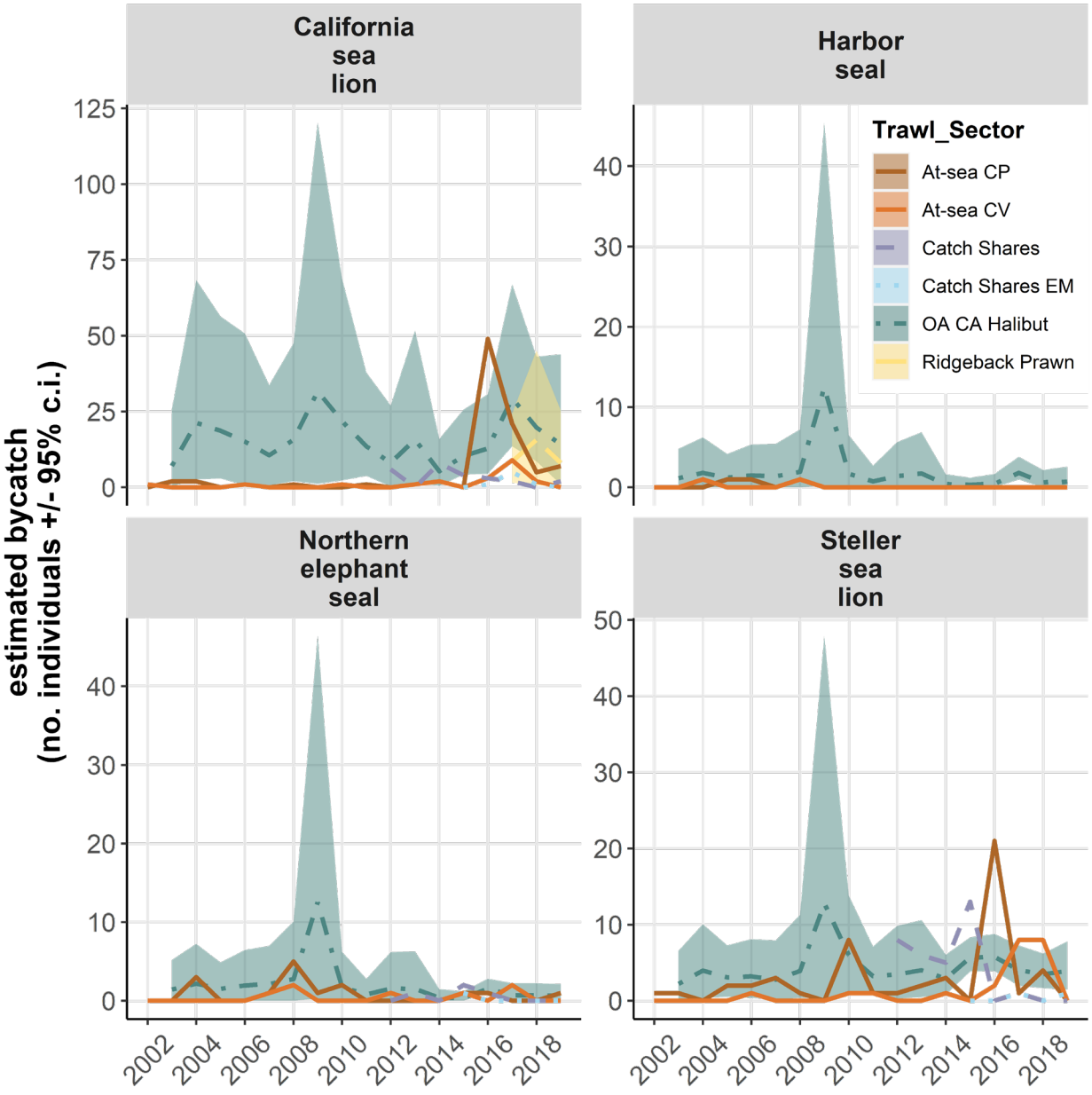

Figure 7. Annual estimated bycatch (number of individuals, 95% CI) of pinniped species caught in U.S. West Coast groundfish trawl fisheries. Lines and colors represent trawl fishery sectors. Estimates with CIs were obtained using the Bayesian method for sectors with <100% monitoring; estimates without CIs are for sectors with 100% monitoring. *CP* = catcher processor vessels; *CV* = catcher vessels delivering to motherships at-sea; *EM* = electronic monitoring; *OA* = open access; *CA* = California.

3.2.2 Catch share trawl fishery

The catch share trawl sector has 100% monitoring via EM or fishery observers and, because marine mammals are large and crew are expected to report all marine mammal bycatch, these vessels have a complete census of mammal bycatch. California and Steller sea lions are the most frequently caught pinnipeds in the catch share trawl fishery (Figure 7, Tables 9 and 10). Northern elephant seals and unidentified sea lions are also occasionally reported. Pacific white-sided dolphin is the only cetacean species that has been taken in the catch share trawl sector (Tables 9 and 10). The entire time series of catch share trawl fishery estimates for both pinnipeds and cetaceans is provided in Supplemental Tables 6 and 7.

Prior to the start of the catch share program in 2011, the limited entry trawl sector also recorded takes of those species listed above in the catch share trawl fishery. The limited entry trawl sector had less than 100% monitoring. Estimates (rather than a complete census) of total fleetwide bycatch prior to 2011 are provided in Supplemental Table 8. In addition to the species mentioned above, there was also estimated a small number of Risso's dolphin bycatch in the limited entry trawl fishery prior to 2011 (Supplemental Table 8).

Table 9. Estimated marine mammal mortality among the U.S. West Coast catch share vessels fishing with bottom trawl (BT) gears, 2015–19. Because vessels in this fishery are monitored 100%, we assume that error around the values presented here is zero (0), so confidence intervals and coefficients of variation are not estimated.

Sector	Gear	Species	2015	2016	2017	2018	2019
Catch share	BT	California sea lion	4.00	3.00	10.00	4.00	2.00
Catch share	BT	Northern elephant seal	2.00	1.00	0.00	0.00	0.00
Catch share	BT	Pacific white-sided dolphin	2.00	0.00	0.00	0.00	0.00
Catch share	BT	Steller sea lion	13.00	0.00	13.00	9.00	0.00

Table 10. Estimated marine mammal mortality among the U.S. West Coast catch share vessels using electronic monitoring (EM) equipment and fishing with bottom and midwater trawl (BMT) gears, 2015–19. Because vessels in this fishery are monitored 100%, we assume that error around the values presented here is zero (0), so confidence intervals and coefficients of variation are not estimated.

Sector	Gear	Species	2015	2016	2017	2018	2019
Catch share EM	BMT	California sea lion	0.00	1.00	6.00	1.00	0.00
Catch share EM	BMT	Northern elephant seal	1.00	0.00	0.00	0.00	0.00
Catch share EM	BMT	Pacific white-sided dolphin	0.00	0.00	1.00	0.00	0.00
Catch share EM	BMT	Sea lion, unidentified	0.00	1.00	2.00	1.00	2.00
Catch share EM	BMT	Steller sea lion	0.00	0.00	1.00	1.00	1.00

3.2.3 California halibut

The OA California halibut fishery has only documented takes of pinnipeds, mostly California and Steller sea lions, but also a few northern elephant and harbor seals (Figure 7, Table 11, Supplemental Table 9).

Prior to the 2011 catch share program, the limited entry trawl vessels (see Section 3.2.2) fished in the California halibut fishery and comprised the limited entry California halibut fishery. Since 2011, estimates for these vessels are included in the catch share trawl fisheries. Estimates for the limited entry California halibut sector prior to 2011 are presented in Supplemental Table 10.

Table 11. Estimated marine mammal mortality (95% CI) among the U.S. West Coast OA CA halibut vessels fishing with bottom trawl (BT) gears, 2015–19. Estimates, 95% CIs, and coefficients of variation for each species and year in the entire time series can be found in the Supplemental Tables.

Sector	Gear	Species	2015	2016	2017	2018	2019
OA CA halibut	BT	California sea lion	12.32 (4–28)	15.88 (5–39)	35.18 (14–78)	24.21 (9–55)	37.60 (19–74)
OA CA halibut	BT	Harbor seal	0.42 (0–2)	0.59 (0–3)	2.11 (1–5)	0.80 (0–3)	1.95 (1–5)
OA CA halibut	BT	Steller sea lion	6.80 (3–12)	6.82 (3–12)	5.21 (1–11)	4.38 (1–9)	9.44 (5–15)
OA CA halibut	BT	Northern elephant seal	0.22 (0–2)	1.32 (1–3)	0.61 (0–3)	0.44 (0–2)	0.52 (0–3)

3.2.4 California prawn

The California ridgeback prawn fishery has only carried fishery observers since 2017, and the only observed marine mammal bycatch in this fishery is California sea lions (Figure 7, Table 12).

Table 12. Estimated marine mammal mortality (95% CI) among the U.S. West Coast ridgeback prawn vessels fishing with shrimp trawl (ST) gears, 2015–19. Estimates, 95%CIs, and coefficients of variation for each species and year in the entire time series can be found in the Supplemental Tables.

Sector	Gear	Species	2017	2018	2019
Ridgeback prawn	ST	California sea lion	9.12 (1–27)	8.52 (0–28)	9.31 (0–29)

3.2.5 California sea cucumber

The California sea cucumber fishery has only carried fishery observers since 2017, and the only observed marine mammal bycatch in this fishery was a single California sea lion during the period 2017–19. We do not present estimates of takes in this fishery because the low observation rate and few vessels in the fleet result in confidential data (<3 vessels in a stratum).

FOS also places fishery observers on trawl vessels in the Washington, Oregon, and California state ocean shrimp (a.k.a. pink shrimp) fisheries. Fishery observers have not witnessed any marine mammal takes in these fisheries.

3.3 Hook-and-Line Fisheries

Hook-and-line fisheries, which includes LE sablefish, LE daily trip limits (DTL) fixed gear, catch share, and nearshore fisheries in Oregon and California, regularly catch pinnipeds—mostly California sea lions, harbor seals, and northern elephant seals, but also a few Steller sea lions, northern fur seals, and unidentified sea lions and pinnipeds (Table 13, Figure 8). The only cetacean species observed caught by hook-and-line fisheries is common bottlenose dolphin (Table 13). The entire time series of hook-and-line fishery estimates for both pinnipeds and cetaceans is provided in Supplemental Table 12.

Table 13. Estimated marine mammal mortality (95% CI) among the U.S. West Coast vessels fishing with hook-and-line (H&L) gears, 2015–19. Estimates, 95% CIs, and coefficients of variation for each species and year in the entire time series can be found in the Supplemental Tables.

Gear	Species	2015	2016	2017	2018	2019
H&L	California sea lion	6.93 (2–13)	6.02 (2–11)	12.20 (6–19)	7.53 (3–14)	6.10 (2–11)
H&L	Common bottlenose dolphin	0.71 (0–3)	0.54 (0–3)	0.73 (0–3)	0.72 (0–3)	0.86 (0–3)
H&L	Harbor seal	2.27 (0–5)	1.73 (0–5)	1.92 (0–5)	2.40 (0–5)	2.72 (0–7)
H&L	Northern elephant seal	3.98 (1–8)	1.25 (0–3)	1.12 (0–3)	2.98 (0–7)	0.99 (0–3)
H&L	Pinniped, unidentified	1.86 (0–5)	0.74 (0–3)	0.91 (0–3)	0.89 (0–3)	1.04 (0–3)
H&L	Sea lion, unidentified	0.29 (0–0)	0.48 (0–0)	0.47 (0–0)	0.40 (0–0)	0.38 (0–0)
H&L	Steller sea lion	0.21 (0–0)	2.34 (0–5)	0.35 (0–0)	0.27 (0–0)	0.27 (0–0)

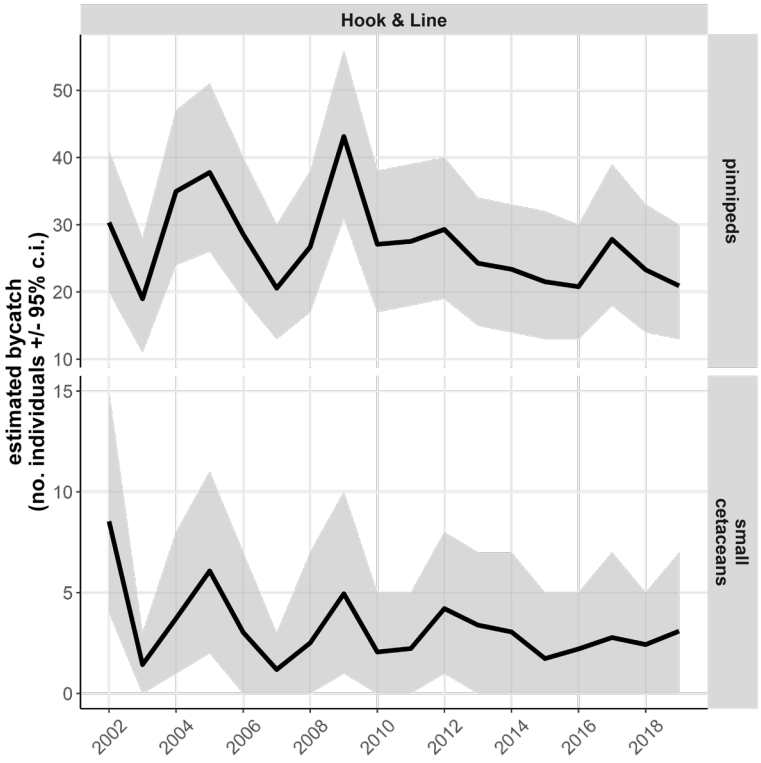

Figure 8. Annual estimated bycatch (number of individuals, 95% CI) of pinnipeds and small cetaceans in U.S. West Coast groundfish hook-and-line fisheries. The small cetacean estimates are exclusively common bottlenose dolphins (*Tursiops truncatus*) from the LE DTL fixed gear fishery.

3.3.1 Limited entry sablefish

To date, the limited entry sablefish hook-and-line fishery has exclusively taken pinnipeds, mostly California sea lions, northern elephant seals, and, in lesser amounts, northern fur seals, Steller sea lions, and unidentified sea lions and pinnipeds (Figure 9, Table 14). The entire time-series of limited entry sablefish hook-and-line fishery estimates for pinnipeds is provided in Supplemental Table 13.

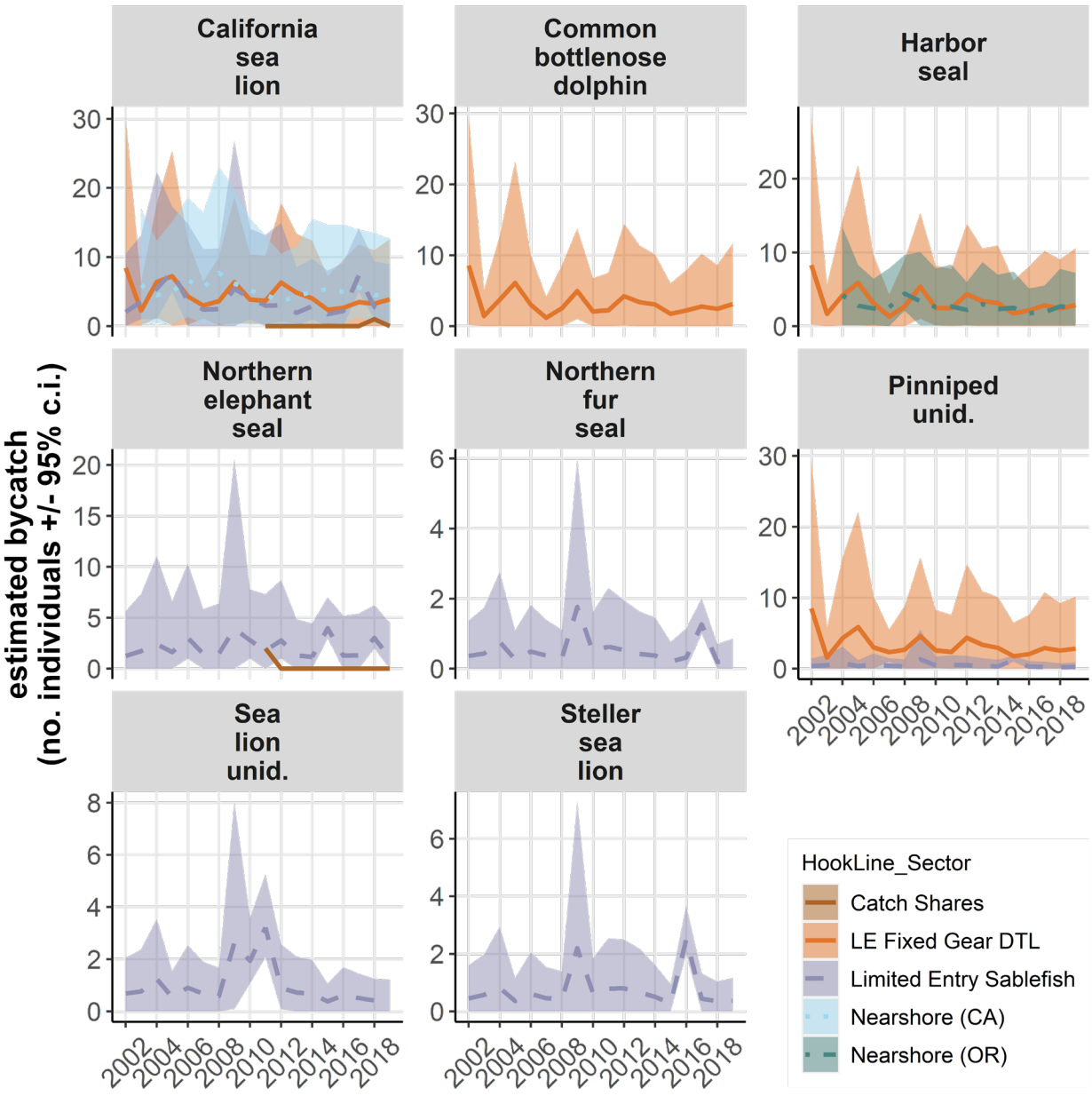

Figure 9. Annual estimated bycatch (number of individuals, 95% CI) of pinniped species caught in U.S. West Coast groundfish hook-and-line fisheries. Lines and colors represent hook-and-line fishery sectors. *LE* = limited entry, *DTL* = daily trip limits, *CA* = California, *OR* = Oregon.

Table 14. Estimated marine mammal mortality (95% CI) among the U.S. West Coast limited entry (LE) sablefish vessels fishing with hook-and-line (H&L) gears, 2015–19. Estimates, 95% CIs, and coefficients of variation for each species and year in the entire time series can be found in the Supplemental Tables.

Sector	Gear	Species	2015	2016	2017	2018	2019
LE sablefish	H&L	California sea lion	1.73 (0–9)	2.10 (0–10)	7.02 (5–15)	2.66 (1–9)	1.71 (0–8)
LE sablefish	H&L	Northern elephant seal	3.98 (3–8)	1.25 (0–6)	1.12 (0–5)	2.98 (2–7)	0.99 (0–5)
LE sablefish	H&L	Pinniped, unidentified	1.15 (1–2)	0.19 (0–2)	0.18 (0–1)	0.15 (0–1)	0.15 (0–1)
LE sablefish	H&L	Sea lion, unidentified	0.29 (0–2)	0.48 (0–2)	0.47 (0–2)	0.40 (0–2)	0.38 (0–2)
LE sablefish	H&L	Steller sea lion	0.21 (0–1)	2.34 (2–4)	0.35 (0–2)	0.27 (0–2)	0.27 (0–2)

3.3.2 Limited entry fixed gear daily trip limits (DTL)

The LE fixed gear DTL fishery is the only hook-and-line fishery that has recorded taking any cetacean: the common bottlenose dolphin (Figure 9, Table 15). This fishery also takes small numbers of California sea lions, harbor seals, and unidentified pinnipeds (Figure 9, Table 24). The entire time-series of LE fixed gear DTL hook-and-line fishery estimates for both pinnipeds and cetaceans is provided in Supplemental Table 14.

Table 15. Estimated marine mammal mortality (95% CI) among the U.S. West Coast limited entry (LE) fixed gear daily trip limits (DTL) vessels fishing with hook-and-line (H&L) gears, 2015-19. Estimates, 95% CIs, and coefficients of variation for each species and year in the entire time series can be found in the Supplemental Tables.

Sector	Gear	Species	2015	2016	2017	2018	2019
LE fixed gear DTL	H&L	California sea lion	1.25 (0–5)	0.95 (0–4)	1.26 (0–5)	1.25 (0–5)	1.51 (0–5)
LE fixed gear DTL	H&L	Common bottlenose dolphin	0.71 (0–3)	0.54 (0–3)	0.73 (0–4)	0.72 (0–4)	0.86 (0–4)
LE fixed gear DTL	H&L	Pinniped, unidentified	0.71 (0–3)	0.55 (0–3)	0.73 (0–3)	0.74 (0–3)	0.89 (0–4)
LE fixed gear DTL	H&L	Harbor seal	0.71 (0–4)	0.53 (0–3)	0.73 (0–4)	0.75 (0–4)	0.86 (0–4)

3.3.3 Catch share hook-and-line fishery

Only a single California sea lion has been taken in recent years in the catch share hook-and-line fishery. A northern elephant seal was taken in the first year of the catch share hook-and-line fishery (2011), but none have been taken since then (Figure 9, Table 16, Supplemental Table 15).

Table 16. Estimated marine mammal mortality among the U.S. West Coast catch share vessels fishing with hook-and-line gears, 2015–19. Because vessels in this fishery are monitored 100%, we assume that error around the values presented here is zero (0), so confidence intervals and coefficients of variation are not estimated.

Sector	Gear	Species	2015	2016	2017	2018	2019
Catch share	H&L	California sea lion	0.00	0.00	0.00	1.00	0.00
Catch share	H&L	Northern elephant seal	0.00	0.00	0.00	0.00	0.00

3.3.4 Nearshore

The California nearshore hook-and-line fishery has only taken California sea lions (Figure 9, Table 17, Supplemental Table 16). The Oregon nearshore hook-and-line fishery has only taken harbor seals (Figure 9, Table 18, Supplemental Table 17).

FOS also places fishery observers on hook-and-line vessels in the open access fixed gear fishery and in the Pacific halibut (*Hippoglossus stenolepis*) commercial directed fishery. Fishery observers have not witnessed any marine mammal takes in these fisheries.

Table 17. Estimated marine mammal mortality (95% CI) among the U.S. West Coast CA nearshore vessels fishing with hook-and-line gears, 2015–19. Estimates, 95% CIs, and coefficients of variation for each species and year in the entire time series can be found in the Supplemental Tables.

Sector	Gear	Species	2015	2016	2017	2018	2019
CA nearshore	H&L	California sea lion	3.95 (0–12)	2.97 (0–9)	3.92 (1–10)	2.62 (0–8)	2.88 (0–9)

Table 18. Estimated marine mammal mortality (95% CI) among the U.S. West Coast OR nearshore vessels fishing with hook-and-line gears, 2015–19. Estimates, 95% CIs, and coefficients of variation for each species and year in the entire time series can be found in the Supplemental Tables.

Sector	Gear	Species	2015	2016	2017	2018	2019
CA nearshore	H&L	Harbor seal	1.56 (0–6)	1.19 (0–5)	1.19 (0–4)	1.65 (0–6)	1.86 (0–6)

3.4 Pot Fisheries

The U.S. West Coast groundfish fisheries using pot gear are the only fisheries that have recorded humpback whale bycatch (Table 19, Figure 10, Supplemental Table 18). Pot fisheries also occasionally take northern elephant seals (Table 19, Supplemental Table 18).

Table 19. Estimated marine mammal mortality (95% CI) among the U.S. West Coast vessels fishing with pot gears, 2015–19. Estimates, 95% CIs, and coefficients of variation for each species and year in the entire time series can be found in the Supplemental Tables.

Gear	Species	2015	2016	2017	2018	2019
Pot	Humpback whale	1.55 (0–5)	2.45 (0–5)	1.47 (0–3)	1.19 (0–3)	1.16 (0–3)
Pot	Northern elephant seal	0.00 (0–0)	0.00 (0–0)	0.00 (0–0)	0.00 (0–0)	1.00 (0–3)

3.4.1 Limited entry sablefish

A humpback whale was documented entangled in a pot buoy line by a fishery observer on an LE sablefish pot vessel in 2014. No humpback whales have been entangled in LE sablefish pot gear in recent years, which, along with high levels of observer coverage (Supplemental Table 35), contributes to the low estimates of bycatch and uncertainty in this fishery (Figure 10, Table 20, Supplemental Table 19).

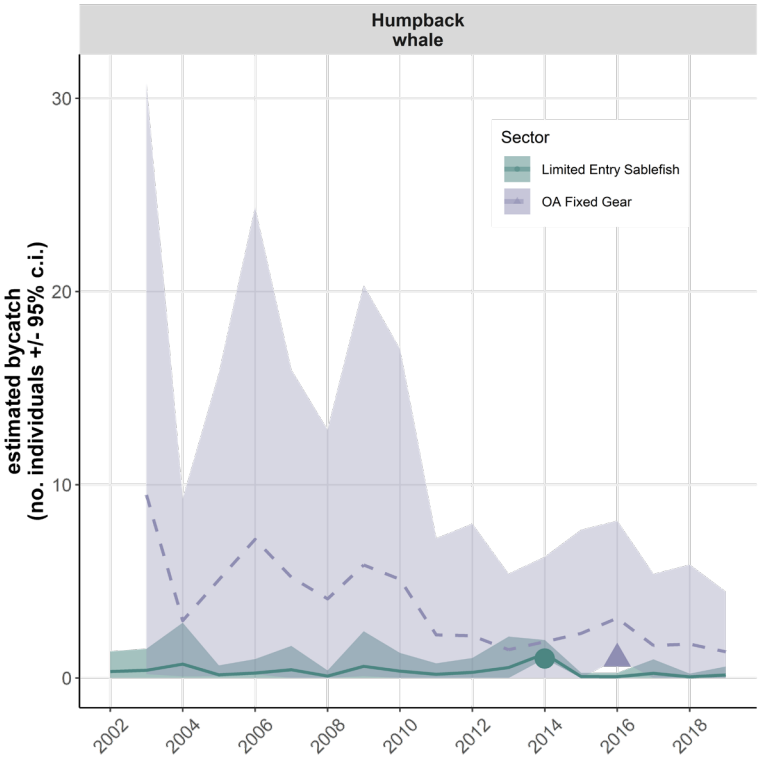

Figure 10. Annual estimated bycatch (number of individuals, 95% CI) of humpback whales caught in U.S. West Coast groundfish pot fisheries. Lines and colors represent pot fishery sectors, points indicate actual takes. *OA* = open access.

Table 20. Estimated marine mammal mortality (95% CI) among the U.S. West Coast limited entry (LE) sablefish vessels fishing with pot gears, 2015–19. Estimates, 95% CIs, and coefficients of variation for each species and year in the entire time series can be found in the Supplemental Tables.

Sector	Gear	Species	2015	2016	2017	2018	2019
LE sablefish	Pot	Humpback whale	0.05 (0–1)	0.06 (0–1)	0.13 (0–1)	0.05 (0–1)	0.13 (0–1)

3.4.2 Open access fixed gear

A humpback whale was documented entangled in a pot buoy line by a fishery observer on an open access pot vessel in 2016. The recency of this event, along with low levels of observer coverage in the OA pot fishery (Supplemental Table 36), contributes to the higher estimates of bycatch and uncertainty in this fishery than in the LE sablefish fishery (Figure 10, Table 21, Supplemental Table 20).

Table 21. Estimated marine mammal mortality (95% CI) among the U.S. West Coast open access (OA) fixed gear vessels fishing with pot gears, 2015–19. Estimates, 95% CIs, and coefficients of variation for each species and year in the entire time series can be found in the Supplemental Tables.

Sector	Gear	Species	2015	2016	2017	2018	2019
OA fixed gear	Pot	Humpback whale	1.50 (0–6)	2.38 (1–7)	1.34 (0–5)	1.14 (0–5)	1.03 (0–4)

3.4.3 Catch share pot fishery

In 2019, electronic monitoring in the catch share pot fishery recorded a northern elephant seal take (Table 22, Supplemental Table 21).

FOS also places fishery observers on pot vessels in the California and Oregon nearshore fisheries. Fishery observers have not witnessed any marine mammal takes in these fisheries.

Table 22. Estimated marine mammal mortality among the U.S. West Coast catch share vessels using electronic monitoring (EM) equipment and fishing with pot gears, 2015–19. Because vessels in this fishery are monitored 100%, we assume that error around the values presented here is zero (0), so confidence intervals and coefficients of variation are not estimated.

Sector	Gear	Species	2015	2016	2017	2018	2019
Catch share EM	Pot	Northern elephant seal	0.00	0.00	0.00	0.00	1.00

3.5 Marine Mammal Nonlethal Interactions and Sightings

In addition to interactions that are lethal or cause serious injury, both A-SHOP and WCGOP collect information regarding marine mammal interactions that are neither lethal nor likely to cause injury. Interactions are defined here as any marine mammal that comes into contact with the vessel, gear, catch, or vessel discharge (e.g., offal, discards, vessel trash, etc.). Sightings of mammals that do not interact with the vessel or vessel discharge in any manner are also recorded. Collecting data on marine mammal mortalities and injuries is the highest priority for observers. Observers are also instructed to document all nonlethal interactions and sightings of marine mammal species. However, neither A-SHOP nor WCGOP has a formal sampling design for systematically documenting nonlethal interactions and sightings in a statistically rigorous framework. Furthermore, observers are not required to set aside time during every day to record sightings. Therefore, nonlethal interactions and sighting observations are considered opportunistic, and statistical models (e.g., to estimate unobserved nonlethal interactions) are not applied to these data. Furthermore, nonlethal and sighting observations reported here are limited in scope to vessel location, which is driven by fishing activity. See Tables 2 and 3 for the number of observed nonlethal interactions and sightings for each species for all years combined. Maps of nonlethal interactions and sightings by group and species are provided in Figures 11–13.

3.5.1 Northern right whale dolphin (*Lissodelphis borealis*)

Northern right whale dolphins are endemic to temperate waters of the North Pacific Ocean. There is currently only one recognized stock off the U.S. West Coast (Carretta et al. 2020b). Surveys suggest that this species undergoes seasonal migrations from California waters during the colder months to Oregon and Washington waters as water temperatures increase (as summarized in Carretta et al. 2020b). Because of both seasonal and interannual migrations and changes in abundance, presumably due to changes in water temperature and other oceanographic conditions, long-term population trends are not currently available for this

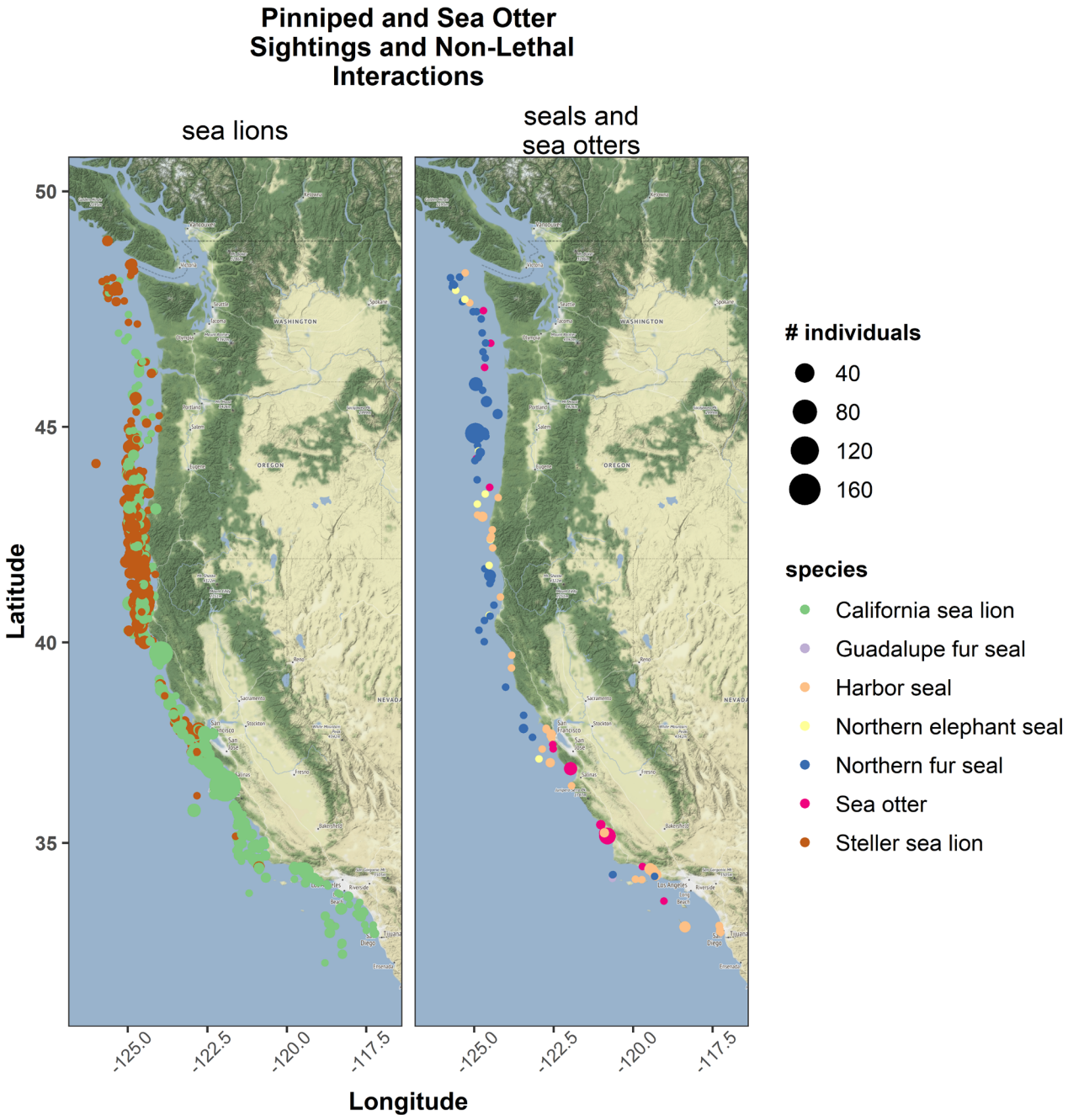

Figure 11. Spatial distribution of observed nonlethal interactions and sightings of pinnipeds (left) and sea otters (right) from observers on fishing vessels along the U.S. West Coast (WA, OR, CA; 2002–19). Data are not considered to be randomly sampled. Observations were removed if the sighting position occurred on land.

species (Carretta et al. 2020b). The estimated PBR for northern right whale dolphins is 179 animals per year (Carretta et al. 2020b). This species is not listed under the ESA or as depleted under the MMPA (Carretta et al. 2020b), and is considered of least concern by the IUCN (Table 2; Braulik and Jefferson 2018). The only recorded take of this species has been in the 100% observed at-sea hake catcher vessel fleet delivering to motherships, in 2016 (Table 8).

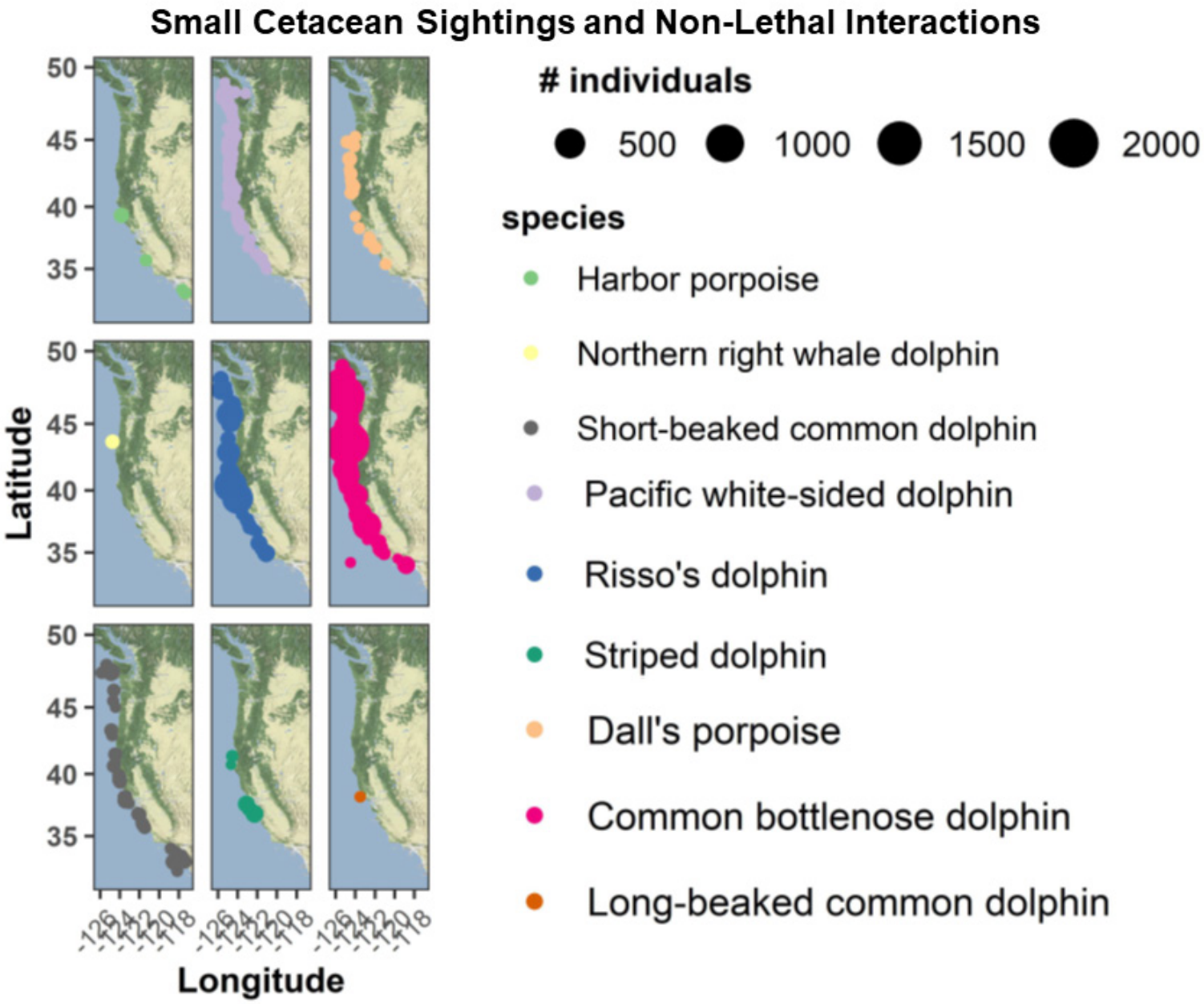

Figure 12. Spatial distribution of observed nonlethal interactions and sightings of small cetaceans (i.e., dolphins and porpoises) from observers on fishing vessels along the U.S. West Coast (WA, OR, CA; 2002–19). Data are not considered to be randomly sampled. Observations were removed if the sighting position occurred on land.

3.5.2 Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)

Pacific white-sided dolphins are found throughout the North Pacific Ocean and inhabit the continental shelf and slope areas of the U.S. West Coast. Geographic distributions for this species are not well understood, and the population along the entire coast is managed as a single unit (Carretta et al. 2009). Pacific white-sided dolphins are thought to move seasonally in a north–south direction along the U.S. West Coast. Forney and Barlow (1998)

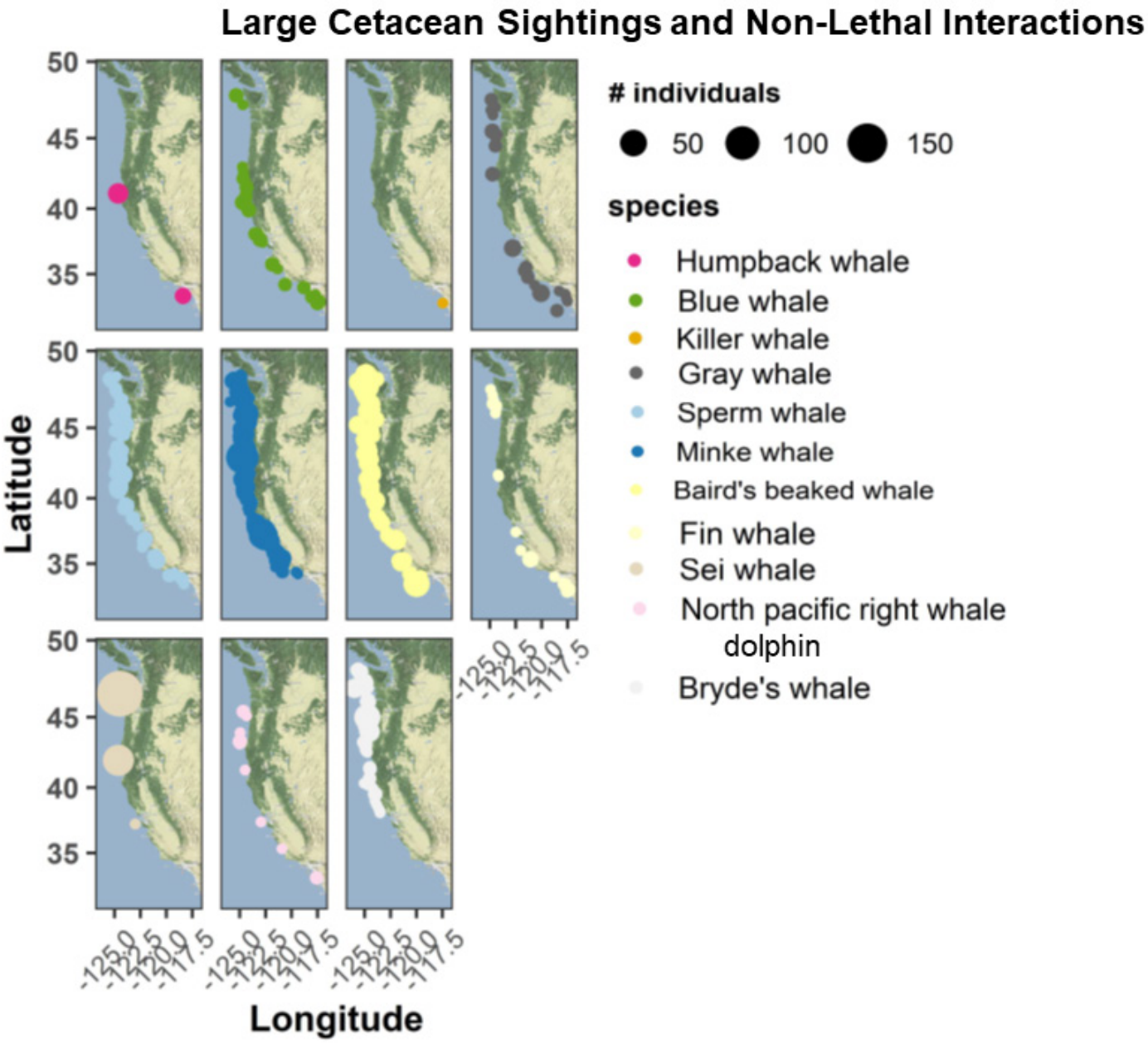

Figure 13. Spatial distribution of observed nonlethal interactions and sightings of large cetaceans (i.e., whales) from observers on fishing vessels along the U.S. West Coast (WA, OR, CA; 2002–19). Data are not considered to be randomly sampled. Observations were removed if the sighting position occurred on land.

found that this species was rare off of Southern California in the summer, but was present in the winter. Aerial surveys conducted by Green et al. (1992) off the coast of Oregon and Washington indicate that Pacific white-sided dolphins are most abundant in these areas in late spring and early summer. Although these findings suggest seasonal movement, the exact timing of this movement is not clear and could vary from year to year depending on variable water temperatures along the coast, or other factors (Forney and Barlow 1998).

Genetic, behavioral, and distributional differences exist between populations north of Point Conception, California, Southern California, and the high seas of the North Pacific (summarized in Carretta et al. 2020b). However, the stocks are not identifiable by sight in the field and, therefore, all stocks are managed as a single unit (Carretta et al. 2020b). The estimate of the population size along the U.S. West Coast is 26,814 individuals, with a PBR of 191 Pacific white-sided dolphins per year. U.S. West Coast groundfish fisheries take an estimated zero to two dolphins per year (Table 5, Supplemental Table 2), all of which have been taken in trawl fisheries (Table 6).

3.5.3 Other species

Historically, several other small cetacean species have been recorded as bycatch in the fisheries examined here. These include harbor porpoise (*Phocoena phocoena*), Risso's dolphin (*Grampus griseus*), and Dall's porpoise (*Phocoenoides dalli*), but none of these species have been caught since 2011 (Supplemental Table 2). Sightings and nonlethal interactions between vessels and these species are mapped in Figure 12.

Guadalupe fur seals (*Arctocephalus townsendi*) are listed as threatened in U.S. waters under the ESA, which makes them both depleted and a strategic stock under the MMPA (Carretta et al. 2020b). However, this species is of least concern globally according to the IUCN (Aurioles-Gamboa 2015). Guadalupe fur seals have only had a single nonlethal interaction with U.S. West Coast groundfish fisheries (Table 3), and have had no takes or sightings.

Sea otters (*Enhydra lutris*) are divided into two subspecies which are treated as separate stocks: 1) a Washington coast stock of northern sea otters (*Enhydra lutris kenyoni*) is not listed under the ESA nor as depleted under the MMPA, although they are considered "State endangered" by the state of Washington (USFWS 2018); and 2) a southern sea otter stock (*Enhydra lutris nereis*) inhabits the nearshore waters of the California coast from San Mateo County south to Santa Barbara (USFWS 2017). The southern stock of sea otters is considered threatened under the ESA, a depleted and strategic stock under the MMPA, and is fully protected under California state laws (USFWS 2017). Sea otters are considered endangered by the IUCN (Table 3; Doroff and Burdin 2015). Sea otters are sometimes sighted by fisheries observers in U.S. West Coast groundfish fisheries, but only one nonlethal interaction and no takes have been recorded in these fisheries (Table 3). The majority of sightings of sea otters have occurred south of San Francisco, with only a few off the coast of Washington and two observations off the coast of Oregon (Figure 11).

3.6 Conclusions

The majority of marine mammals killed by U.S. West Coast groundfish fisheries are pinnipeds. Most of these are California sea lions, followed by Steller sea lions, both of which are most frequently captured in trawl gears. Northern elephant and harbor seals are the most frequently caught seals, with roughly similar numbers being caught in both trawl and hook-and-line fisheries. In 2019, a northern elephant seal was caught for the first time in a pot fishery (catch share EM). Between two and four unidentified pinnipeds or sea lions are also killed each year in these fisheries. Neither guadalupe fur seals nor sea otters have been observed taken or killed by these fisheries.

The majority of small cetaceans taken in the U.S. West Coast groundfish fisheries are common bottlenose dolphins, followed by Pacific white-sided dolphins. In 2016, the first record of a northern right whale dolphin take occurred in the Pacific hake catcher vessels delivering to motherships at sea. A number of small cetacean species that were killed by trawl fisheries have not been observed as bycatch since the catch share program was implemented in 2011. Humpback whales have been taken in both the LE sablefish and the OA fixed gear pot fisheries, and represent the only ESA-listed species taken by these fisheries, as well as the only large cetacean.

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Appendix A: NWFSC Fisheries Observation Science Program

A.1 At-Sea Hake Observer Program (A-SHOP)

A-SHOP observes the fishery that catches and either processes or delivers Pacific hake at sea (a.k.a. Pacific whiting, *Merluccius productus*, hereafter: hake), including non-tribal catcher–processors and catcher vessels delivering to motherships (Table A-1). A-SHOP has conducted observations of the U.S. West Coast at-sea hake fishery since 2001. Prior to 2001, observer coverage of the U.S. West Coast at-sea hake fishery was conducted by the North Pacific Groundfish Observer Program. Information on A-SHOP and the data collection methods used can be found in the A-SHOP observer manual (NWFSC 2021a). The at-sea hake fishery has mandatory observer coverage, with each vessel over 38 meters carrying two observers. Beginning in 2011, under individual fishing quota (IFQ = catch share)/Co-op Program management, all catcher vessels that deliver catch to motherships are required to carry observers or use electronic monitoring equipment. With one or two observers on board each vessel during every trip, nearly 100% of tows are sampled (Somers et al. 2021).[1] For the purposes of bycatch estimation, we assume that any observed marine mammals represent a complete census of the mammals in the catch. This assumption is justified because the large size of marine mammals makes them easy to observe and sample, even when mixed with large quantities of fish catch. Crew are required to report any marine mammal to the on-vessel observer(s).

A.2 West Coast Groundfish Observer Program (WCGOP)

The WCGOP program was established in May 2001 by the National Marine Fisheries Service (NMFS) in accordance with the Pacific Coast Groundfish Fishery Management Plan (USOFR 2006). This regulation requires all vessels that catch groundfish in the U.S. EEZ, from 5.6–370 km offshore, to carry an observer when notified to do so by NMFS or its designated agent. Subsequent state rule-making and permitting processes have extended NMFS's ability to require some vessels fishing in the 0–5.6-km state territorial zone to carry observers.

WCGOP observes multiple federal groundfish fisheries, including catch share (IFQ) vessels that deliver groundfish and Pacific hake to shoreside processors, limited entry (LE) and open access (OA) fixed gear fisheries, and the directed fishery targeting Pacific halibut (Tables A-1 and A-2). WCGOP also observes several state-permitted fisheries that target or incidentally catch groundfish, including the Washington, Oregon, and California pink shrimp trawl fisheries, the Oregon and California nearshore fixed gear fisheries, the California halibut trawl fishery, the California ridgeback prawn fishery, and the California sea cucumber trawl fishery (Table A-3).

Shoreside catch share (IFQ) vessels are required to carry an observer on 100% of fishing trips. In 2015, some vessels obtained an exempted fishing permit (EFP) which allowed them to carry electronic monitoring (EM) equipment in lieu of a human observer. These

[1]Somers, K. A., J. E. Jannot, K. E. Richerson, V. J. Tuttle, and J. T. McVeigh. 2021. Fisheries Observation Science Program Coverage Rates, 2002–20. U.S. Department of Commerce, NOAA Data Report NMFS-NWFSC-DR-2021-02. DOI: 10.25923/9rpa-9t92

EM vessels have 100% monitoring of catch of quota species; scientific observers are placed on about 30% of catch share EM vessels that sort and discard at-sea to provide estimates of nonquota species catch. Crew are required to present any marine mammal to the on-vessel cameras when being monitored by EM. In non-catch share fishery sectors, there is no mandate for 100% coverage, and the amount of observer coverage varies among sectors and, within sectors, among years (Somers et al. 2021). In these sectors, permits are selected for observation by WCGOP using a random sampling design without replacement. First, WCGOP determines the amount of time (based on available resources) it will take to observe the entire fleet; this is termed the selection cycle. Next, WCGOP aggregates locations along the U.S. West Coast into port groups. The permits or vessels in each fishery sector are assigned to a port group based on the location of their previous year's landings. Within each port group, the permits or vessels are randomly selected for coverage. Permits in the LE bottom trawl fishery prior to the catch share program (2002–10), LE sablefish fixed gear nonendorsed (nonprimary), OA fixed gear, Oregon and California nearshore, California halibut, state-managed pink shrimp, California ridgeback prawn, and California sea cucumber fisheries are selected for one- or two-month periods, which coincide with cumulative trip limit periods used in management. LE fixed gear sablefish endorsed (primary) permits are selected for the entire sablefish season (1 April–31 October) until their quota is caught. The directed Pacific halibut fishery is selected for the entire season, which consists of multiple short openings per year. This selection process is designed to produce a logistically feasible sampling plan with a distribution of observations throughout the entire geographic and temporal range of each fishery. Once a permit or vessel has been selected for coverage, WCGOP attempts to observe all trips and sets that the vessel makes during the coverage period.

The annual percentage of observer coverage in nonhake fisheries ranges from <1% to over 30% (Somers et al. 2021), as defined by the proportion of targeted fishery landings that are observed. Coverage varies among fisheries based on priority. Higher-priority fisheries receive the highest observer coverage. A list of fisheries in order of coverage priority can be found in the WCGOP manual (NWFSC 2021b).

WCGOP observers monitor and record catch data on commercial fishing vessels by following protocols in the WCGOP manual (NWFSC 2021b). Observer sampling focuses on discarded catch, and supplements existing fish ticket landing receipt data to inform weights of total catch. Observers generally sample 100% of tows/sets made during a trip. On trawlers, the total weight of discarded catch is estimated, and the discarded catch is then sampled for species composition. The species composition sample could represent either a complete census or a subsample of all discarded catch. On vessels using either hook-and-line or pot gear, observers sample 50–100% of the catch from each set, similar to A-SHOP sampling.

Table A-1. A description of permits, gears used, target groups, vessel length range, fishing depth range, and management of fishery sectors and subsectors in federally managed and monitored U.S. West Coast groundfish catch share fisheries which use individual fishing quotas (IFQ) to manage certain species. Observer coverage in these fisheries is 100%, except for vessels using electronic monitoring (EM). The catch share program began in 2011; regulations prior to 2011 are excluded. For brevity, management descriptors are generalized and are not meant to be complete or comprehensive. Vessel lengths and fishing depths are based on observed vessels and might not represent the fleet as a whole. *LE* = limited entry, *MW* = midwater, *MSCV* = mothership catcher vessel, *CP* = catcher–processor, *BT* = bottom trawl, *H&L* = hook-and-line, *IFQ* = individual fishing quota.

Sector	Subsector	Permit[a]	Gear	Target	Vessel length (m)	Depth (m)	Management
LE trawl	LE trawl	LE with trawl endorsement	BT H&L pot	Groundfish[b]	15–40	10–1,600	IFQ[f]
	MW rockfish	LE with trawl endorsement	MW trawl	MW rockfish[c]	15–33	>70	IFQ[f]
	MW hake	LE with trawl endorsement	MW trawl	Hake[d]	17–40	>70	IFQ[f]
At-sea hake	MSCV	LE with MSCV endorsement	MW trawl	Hake[d]	8–138[e]	53–460[e]	IFQ[f]
	CP	LE with CP endorsement	MW trawl	Hake[d]	82–115	60–570	IFQ
	Tribal	n/a	MW trawl	Hake[d]	<38	53–460	IFQ

[a] A.k.a. LE permit. All LE permits are issued by NOAA.
[b] Vessels with a California halibut permit, issued by the state of California, can land CA halibut under California's CA halibut fishery regulations.
[c] *Sebastes* spp.
[d] *Merluccius productus*.
[e] Average values for catcher vessels.
[f] Some vessels use EM in lieu of 100% observer coverage.

Table A-2. A description of permits, gears used, target groups, vessel length range, fishing depth range, and management of fishery sectors and subsectors in federally managed and observed U.S. West Coast groundfish non-catch share fisheries. Observer coverage on these vessels is less than 100%. For brevity, management descriptors are generalized and are not meant to be complete or comprehensive. Vessel lengths and fishing depths are based on observed vessels and might not represent the fleet as a whole. *IPHC* = International Pacific Halibut Commission, *OA* = open access, *LE* = limited entry, *FG* = fixed gear.

Sector	Subsector	Permit	Gear	Target	Vessel length (m)	Depth (m)	Management
Non-nearshore fixed gear	Sablefish endorsed	LE permit with FG endorsement and sablefish quota[b]	Longline, pot	Sablefish[d]	7–32	20–1,300	Sablefish tier quotas[h]
	Sablefish nonendorsed[a]	LE permit with FG endorsement, no sablefish quota[b]	Longline, pot	Sablefish, rockfish[e], flatfish[f]	7–32	20–1,300	Trip limits
	OA	n/a	Longline, pot	Sablefish, other groundfish	3–30	20–1,300	Trip limits
IPHC P. halibut directed	—	IPHC P. halibut permit[c]	Longline	P. halibut[g]	3–30	40–400	Trip limits[i]

[a] A.k.a. zero-tier.
[b] A.k.a. LE permit. All LE permits are issued by NOAA.
[c] Issued by IPHC.
[d] *Anoplopomia fimbria*.
[e] *Sebastes* spp.
[f] Pleuronectiformes.
[g] *Hippoglossus stenolepis*.
[h] Seven-month season.
[i] Ten-hour fishing periods south of Point Chehalis, Washington. Legal size = <82 cm.

Table A-3. A description of permits, gears used, target groups, vessel length range, fishing depth range, and management of fishery sectors and subsectors in state-managed, observed fisheries. Observer coverage on these vessels is less than 100%. For brevity, management descriptors are generalized for the given time period and are not meant to be complete or comprehensive. Vessel lengths and fishing depths are based on observed vessels and might not represent the fleet as a whole. OA = open access, BT = bottom trawl, ST = shrimp trawl.

Sector	Permit	Gear	Target	Vessel length (m)	Depth (m)	Management
OA CA halibut	CA halibut permit[b]	BT	CA halibut[d]	9–22	10–200	Fish mainly within the CA halibut trawl grounds. Minimum mesh size. 7-mo season.
Nearshore[a] fixed gear	OR or CA state nearshore permit/ endorsement	Variety of fixed gear[c]	Rockfish[e] Cabezon[f] Greenlings[g]	3–15	<100	Federal and state regulations. Area closures. Minimum mesh size. 2-mo trip limits.
Pink shrimp	WA, OR, or CA state pink shrimp permit	ST	Pink shrimp[h]	11–33	60–800	State regulations. Bycatch reduction devices. Trip limits on groundfish landings.
CA ridgeback prawn	Prawn permit[b]	ST or BT	Golden, spot, ridgeback, or other prawn[i]	9–19	45–700	Oct–May season. Trip limits. Area restrictions. Landing requirements.
CA sea cucumber	Sea cucumber trawl permit[b]	BT	CA sea cucumber[j]	9–12	<100	Logbook requirement. Area and seasonal closures.

[a] The state of Washington does not conduct a nearshore fishery.
[b] Issued by the state of California.
[c] Hand lines, pot gear, stick gear, rod-and-reel.
[d] *Paralichthys californicus*.
[e] *Sebastes* spp.
[f] *Scorpaenichthys marmoratus*.
[g] Hexagrammidae.
[h] *Pandalus jordani*.
[i] Includes *Crangon* spp., *Lysmata californica*, *Pandalus clanae*, *P. jordani*, *P. platyceros*, and *Sicyonia ingentis*.
[j] *Parastichopus californicus*.

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